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Comprehensive School Reform and Elementary Science Education:
A Study of Science Education in the Context of Three School Reform Models

By

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Doctor of Philosophy

Educational Studies

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An abstract of
A dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
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Abstract

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In spite of decades of reform, science education continues to receive minimal attention in urban elementary schools. Although the marginalization of science at the elementary level likely results from a complex set of interrelated factors, recent scholarship suggests that tensions may exist between science education reform and the reform agendas that predominate in urban school districts (Apple, 2006; Hatch, 2002; Pringle & Carrier Martin, 2005; Tate, 2001). Drawing on a conceptual framework that describes the forces and conditions that shape science teaching and learning in urban schools (Knapp and Plecki, 2001), this study examined the relationship between comprehensive school reform and elementary science education in one urban school district. Utilizing survey data, focus groups, interviews, document analysis, and classroom observations, this study examined elementary science education within the context of three comprehensive school reform models: Core Knowledge, Direct Instruction, International Baccalaureate. Specifically, patterns and differences in elementary teachers' personal agency beliefs (Ford, 1992), science teaching practices, and the allocation of time for science education within and across reform models were explored. Consistent with pilot study data, across reform models, teachers tended to express positive capability beliefs; however, teachers in Direct Instruction schools were more likely than teachers in the Core Knowledge and International Baccalaureate reform models to evince negative beliefs about their science teaching context. Substantive differences in science teaching practices and the allocation of time for science were also observed and reported by teachers across the three reform models. Implications for theory, research, and practice are discussed.

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It is rumored that a sign hung in Albert Einstein's office read "not everything that counts can be counted, and not everything that can be counted counts." With this in mind, I have concluded that the mentors, colleagues, and friends who made this work possible, and all the ways in which they have done so, simply cannot be counted. That said, I must acknowledge the teachers and schools that participated in this study. If not for their willingness to share their stories and insights, these pages would be blank. My advisor, Dr. George Engelhard, certainly counts among my most important influences. From the moment he agreed to chair my dissertation committee, Dr. Engelhard's generosity, kindness, and wisdom have enriched my work. I am also indebted to my committee members: Dr. Robert Jensen, Dr. Robert DeHaan, and Dr. Joseph Cadray. There is no doubt that the dialogue, careful consideration, and thoughtful questions provided by this committee of scholars have helped me sharpen my skills as a researcher and writer. In addition, this work is fueled by lessons learned from past and present scholars of Emory's Division of Educational Studies. In particular, I thank Dr. Siddle-Walker for teaching me almost everything I know about conducting qualitative research, Dr. Magnia George for her mentorship and guidance during the beginning stages of this research, and the late, great Dr. Frank Pajares for introducing me to many of the ideas at the heart of this work. I thank the members of my cohort – Khalilah Ali, Curtis Goings, Latrise Johnson, Laura Quaynor, and Vincent Willis – and current students and alumni of the Division – Dr. David Morris, Dr. Vera Stenhouse, Dr. Michelle Purdy, and Nadia Behizedeh - for their never-ending supply of support.

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CHAPTER 1: INTRODUCTION

Statement of the Problem

In spite of longstanding concern for the state of science education and ongoing discourse around a science education reform agenda advocating "Science for All" (Barton & Osborne, 1995; Frazer, 1986; Hodson & Reid, 1988; Lee & Fradd, 1998; Lynch, 2001; Hoffman & Stage, 1993), science has long been marginalized as a "fringe subject" in American elementary schools (Jones et al., 1999; Spillane, Diamond, Walker, Halverson, & Jita, 2001). In their 1978 study, Stake and Easley concluded that:

> Although a few elementary teachers with strong interest and understanding of science were found, the number was insufficient to suggest even half of the nation's youngsters would have a single elementary year in which their teachers would give science a substantive share of the curriculum and do a good job doing it. (p.19)

Decades later, scholars continue to lament that "science class time, especially in the elementary grades, has been reduced to a vestigial organ whereby science is taught using traditional approaches or, in the worst cases, has been excised from the curricular body" (Goldston, 2005, p. 185). This statement accords with the results of a large-scale study of third-grade classrooms that found that teachers devoted only 6% of class time to science (NICHHD, 2005).

The neglect of science education, while widespread in American elementary schools, is particularly intense in urban public schools (Lynch, 2000; Tate, 2001). Although the National Science Education Standards "emphatically reject any situation in science education where some people – for example, members of certain populations – are discouraged from pursuing science and excluded from opportunities to learn science"

(p. 20), serious inequities persist. Students attending urban schools, and more specifically, students from historically marginalized groups who attend urban schools face a sort of double jeopardy when it comes to science education. In addition to working against a legacy of oppression that has historically denied people of color and women access to the sciences, students growing up in high-poverty urban communities continue to be more likely than their counterparts in low-poverty communities to have teachers with little preparation to teach science, to attend schools with scarce resources for science teaching, and to have fewer opportunities to take the courses that would prepare them to pursue advanced coursework and careers in science (Lynch, 2000).

The disconnect between the vision of science education imagined by reformers and the realities of science education in urban elementary classrooms presents a puzzle for science education researchers. Given broad consensus on the importance of science education and decades of standards-based reform, how is it possible that the teaching of elementary science has not yet made the transition from passing fad to accepted practice? What will it take for science to finally secure a permanent place in the elementary curriculum? What catalysts and impediments exist to improving science education in urban elementary schools?

Although the undervaluing of science necessarily results from a complex set of interrelated factors, the failures of science education reform may be exacerbated by the systemic school reform agendas that predominate in large urban districts (Apple, 2006; Hatch, 2002; Pringle & Carrier Martin, 2005; Razze, 2001; Tate, 2001). Knapp & Plecki (2001) identify an array of interdependent policies at the school, district, and state levels that influence science teaching and learning in urban schools. These policies include state standards; teacher recruitment, preparation, and certification policies; professional development and support policies; and assessment and accountability policies. For example, initiatives like the federal No Child Left Behind Act (NCLB) which hold schools accountable for student performance on high-stakes assessments in reading, language arts and mathematics have, as one researcher put it, “accentuated the undervaluing of science education”(Spillane et al., 2001, p. 926). Teachers report scaling back or abandoning science instruction altogether in order to focus on subjects included in state testing and accountability programs. In states where science has been added to assessment programs, there is growing concern that science instruction will be reduced to test preparation (Pringle & Carrier Martin, 2005). Tate (2001) calls for closer examination of possible tensions between the current wave of school reform policy and science education reform, stating that:

> Many have associated the reform of urban schools with accountability models, assessments, and standards. These policy instruments are having an effect on urban schooling. The fundamental question is whether these change mechanisms are producing the desired effect in science education. If they are not, then it is time to challenge them as obstacles to urban school students’ opportunity to learn science, and ultimately to their civil rights (p. 1026).

This study takes up Tate’s fundamental question by exploring the relationship between comprehensive school reform and elementary science education in one urban school district.

Comprehensive school reform is an approach to design-based school improvement that, since the 1990s, has emerged as the “poster child” for scientifically based reform in American education (Rowen, Correnti, Millier, Camburn, 2009).

Comprehensive school reform aims to provide whole-school interventions intended to redesign all aspects of school operations, including professional development, curriculum, and school and classroom management. Over the past decade, thousands of schools, serving millions of students have implemented either self-developed or externally developed CSR models. With federal funding from the 1997 Comprehensive School Reform Demonstration Act and later from No Child Left Behind, CSR models provided by over 600 organizations have been adopted by nearly 7,000 schools across the country (Rowen, Correnti, Millier, Camburn, 2009). As of 2004, between 10 and 20% of elementary schools in the United States had either adopted an externally developed CSR model or implemented a locally developed model.

The U.S. Department of Education defines comprehensive school reform using 11 components that are intended to represent a “comprehensive” and “scientifically based” approach to school reform. Among these components are the recommendations that a CSR models should:

> Integrate a comprehensive design for effective school functioning, including instruction, assessment, classroom management, professional development, parental involvement, and school management, that aligns the school's curriculum, technology, and professional development into a comprehensive school reform plan for school wide change designed to enable all students to meet challenging State content and student academic achievement standards and addresses needs identified through a school needs assessment (cited in Cross, 2004).

Although this recommendation implies that successful CSR models should aim to foster student achievement in all content areas, many popular school reform models focus primarily, and sometimes exclusively, on improving student achievement in literacy and, to a lesser degree, mathematics. For example, in one meta-analysis of studies evaluating comprehensive school reform models (Borman, Hewes, Overman, & Brown, 2003), two of the three reform models designated as having "strong evidence of effectiveness," Direct Instruction and Success For All, emphasize reading and, to a lesser extent, mathematics, but generally do not include a science education component. Further, the extent to which comprehensive school reform models are designed to permit the type of inquiry-based science instruction called by science education reformers remains unclear. To date, there have been no studies examining the effects of comprehensive school reform models on elementary science education.

Purpose of the Study

The purpose of this study is to examine the relationship between comprehensive school reform and science education in one urban school district. The study explores elementary science education within the context of three comprehensive school reform models (Core Knowledge, Direct Instruction, and International Baccalaureate). Specifically, the study investigates possible variations in teachers' science teaching practices, the allocation of time for science, and teachers' personal agency beliefs within and across reform models.

Research Questions

The following research questions guided this study:

1. To what extent do science teaching practices vary across the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?

2. How is time for science allocated in schools implementing the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?

3. To what extent do teachers' personal agency beliefs vary across the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?

Frameworks

Two frameworks provide the conceptual foundation for this study. The primary framework for the study is Knapp and Plecki's framework for the renewal of urban science education. This framework, described in detail below, guided the examination of the relationship between comprehensive school reform and science education. Ford's Motivational Systems Theory and, more specifically, his conception of personal agency beliefs, serve as the basis for examining teachers' beliefs. Each of these frameworks is described below.

Knapp and Plecki's Framework for the Renewal of Urban Science Teaching

Knapp and Plecki (2001) provide a useful conceptual framework for understanding the specific policy signals at work in science education. Within this framework, Knapp and Plecki identify three sets of forces and conditions thought to drive events in urban science classrooms:

1. Interdependent policies at the school, district, state, and national levels that directly impinge on science teachers' work and careers.
2. Investment of resources at all levels and attempts to actualize these resources.

3. A professional, organizational, and community context that influences resource allocation. (p. 1092)

Knapp and Plecki describe an array of interdependent policies that interact with the conditions in urban schools to constitute what they refer to as the *teaching policy environment*. These policies include: curriculum guidance (formalized as standards, curricular frameworks or materials at the school, district, state, and national levels); assessment and accountability policies; teacher recruitment, preparation, and certification policies; hiring, staffing, and assignment policies, professional development and teacher support policies; compensation, reward, and evaluation policies; workplace redesign and support policies; and, policies aimed at special learning needs. Taken together, these policies combine to “present opportunities and constraints, catalysts and barriers, incentives and disincentives” for teachers ultimately responsible for policy implementation (Knapp & Plecki, 2001, p. 1092). The framework further specifies the aspects of science education influenced by this constellation of policies including: what is being taught, how science is being taught, who is teaching whom, student learning and performance, and teacher learning and colleagueship.

In addition to outlining the components of the teaching policy environment, Knapp and Plecki describe four dimensions that can be used to characterize teaching policy environments: coherence, comprehensiveness, intrusiveness, and stability. Coherence is defined as the extent to which the different strands of policy offer mutually supportive guidance for science teaching. Comprehensiveness is the degree to which the array of policies touch all aspects of science teachers’ work. Intrusiveness has to do with whether policies are designed and enacted in ways that make immediate demands on science teachers versus exerting little or no pressure on teacher practice. Stability refers to the extent to which policies remain constant within the teaching policy environment.

While each of these dimensions may be useful in analyzing the relationship between comprehensive school reform and science education at the school level, the issue of coherence is particularly relevant to the examination of compatibility between various comprehensive school reform models and elementary science education within the district featured in this study. Indeed, the movement to adopt comprehensive school reform was, in part, motivated by concerns about a lack of coherence among multiple school reform programs implemented at the elementary level (Cross, 2004; Fullan, 2001).

The Knapp and Plecki framework also outlines important concepts regarding the investment and strategic use of resources for science teaching. The specific resources the framework highlights are: the allocation of time within the day, the week, and the yearlong curriculum, access to natural world phenomena – or representations of them (e.g. material resources, local scientific institutions), the intellectual resources teachers bring to their work (e.g. PCK), and the social resources "residing in teachers' and learners' attitudes toward learning, science, and each other" (p. 1094). Knapp and Plecki present a nested view of resource investment, positing that teachers' access and use of resources is critically influenced by decision-making and investment at the school level. Schools, in turn, rely on the financial, intellectual, and social resources available at the district level.

The strategic use of resources at both the school- and district-levels is mediated by a set of forces within and surrounding urban science classrooms. Knapp and Plecki describe five principle mediators thought to have "profound implications for science teachers' work" (p. 1095): the professional peer community, subject specific instructional leadership, the infrastructure supporting professional development, the supply of potentially available science teachers, and pressures emanating from the city or state setting. Knapp and Plecki further explain the relationship between such forces and the teaching policy environment, stating that they "both mediate the effects of the teaching policy environment on resource use and are themselves shaped by this environment" (1095).

The policy contexts in which elementary teachers are expected to work as agents of science education reform are complex. With layers of interrelated policies being lived out within layers of interrelated contexts (i.e. classroom, school, and district), it is no wonder that science education researchers have so often focused their inquiry on isolated policies and initiatives. Knapp and Plecki's framework, while it is as multidimensional as the arena it seeks to describe, provides a clear starting point for researchers interested in exploring the complex world of elementary science education.

Ford's Motivational Systems Theory

According to Knapp & Plecki's framework, teachers' attitudes and beliefs regarding science education are important social resources within urban science classrooms. For the purposes of this study, Ford's Motivational Systems Theory (MST) will be used as a conceptual lens for viewing elementary teachers' beliefs. According to MST, motivation is comprised of goals and personal agency beliefs. Ford (1992) defines goals as "thoughts about desired states or outcomes that one would like to achieve"

(248) and personal agency beliefs as "anticipatory evaluations about whether one can achieve a goal" (p. 45).

Ford describes two components of personal agency beliefs: capability beliefs and context beliefs. Capability beliefs, which are thought to be synonymous with Bandura's concept of self-efficacy (Haney, et al. , 2000), reflect an individual's expectancies about their own capability to attain certain goals. Context beliefs refer to an individual's expectancies regarding the responsiveness of their environment. Ford argues that, in combination, capability and context beliefs form personal agency beliefs. Drawing on Ford's theory, Lumpe, Haney, and Czerniak (2000) propose that personal agency beliefs can be examined using the Science Teaching Efficacy Beliefs Instrument (STEBI) (Riggs & Enochs, 1990) in conjunction with the Enable (CBATS – E) and Likelihood (CBATS-L) Scales of their Context Beliefs about Teaching Science instrument.

In discussing the interaction between context and capability beliefs, Ford outlines a taxonomy that includes the following ten conceptually distinguishable personal agency belief patterns: Robust, Tenacious, Modest, Fragile, Vulnerable, Self-Doubting, Accepting, Antagonistic, Discouraged, and Hopeless. In his discussion of the taxonomy, Ford notes that while the Robust, Tenacious, and Modest patterns may generally be more adaptive, no single pattern is best for all circumstances. For example, a Self-Doubting pattern may be much more suitable than a Robust pattern in situations where individuals are engaged in risky behaviors (i.e. compulsive gambling, drinking and driving). A matrix of Ford's ten personal agency belief patterns is presented in Figure 1.

Ford (1992) suggests that “personal agency beliefs play a particularly crucial role in situations that are of the greatest developmental significance - those involving challenging but attainable goals” and that “they are often key targets of intervention for parents, teachers, counselors, and others interested in promoting effective functioning” (pp. 124-125). If we acknowledge that, for elementary teachers, the goals of science education reform fall into this “challenging but attainable” category, teachers’ personal agency beliefs emerge as an important area of inquiry.

For the purposes of this study, personal agency beliefs are conceptualized as elementary teachers’ anticipatory evaluations of their own ability to implement the district’s current science education reform initiative. More specifically, teachers’ personal agency beliefs are viewed in terms of their capability beliefs, their beliefs about the environmental factors that would support effective science teaching, and the likelihood that such factors would occur within their school context.

Significance of the Study

The results of this study will be of interest to educators, school leaders, policy-makers, and designers of science curricula and professional development opportunities. The study is the first to focus on the relationship between comprehensive school reform and elementary science education. These data could heighten school leaders’ awareness of the challenges teachers face and the strategies they employ when integrating reform initiatives at the classroom level. Identifying such school-level strategies could strengthen efforts to implement science reform alongside the variety of initiatives and programs, including comprehensive school reform, that comprise the teaching policy environments in the participating school district. At the same time, a more complete picture of the ways in which the teaching policy environment may influence teachers' beliefs about science education reform has the potential to enhance efforts to select and implement reform initiatives in ways that complement the science education reform agenda.

At the policy level, this study lends insight into teachers' mindsets about science education reform as they interact with assessment, curriculum, and accountability policy. Such insights have the potential to help policymakers anticipate the challenges educators face when simultaneously implementing strands of education policy that may originate from different sources, have discrepant or even competing goals, and require different modes of teaching and learning. To the extent that teachers report success in meeting the demands of both science education reform and comprehensive school reform, the current study documents the teacher beliefs and teaching policy environments that may underlie that success.

Definition of Terms

The following terms are central to the study. For each term, both a general definition and a statement regarding the specific operationalization and use of the term for this study are given.

Capability Beliefs

Capability beliefs are beliefs about one's competency in a certain area or capability to attain a specific goal and are similar to Bandura's self-efficacy construct (Ford, 1992). This study examines elementary teachers' beliefs about their capability to teach science.

Coherence

The extent to which different strands of policy offer mutually supportive guidance for science teaching. For the purpose of this study, coherence is understood as the extent to the Core Knowledge, Direct Instruction, and International Baccalaureate reform models and school and district-level science education initiatives offer mutually supportive guidance for science teaching.

Comprehensive School Reform

A school reform agenda initiated by the district's Superintendent during the 1999-2000 academic year requires all Title 1 schools in the participating district to implement a research-based comprehensive school reform model. This federal legislation defines comprehensive school reform as an approach that:

> integrates a comprehensive design for effective school functioning, including instruction, assessment, classroom management, professional development, parental involvement, and school management, that aligns the school's curriculum, technology, and professional development into a comprehensive school reform plan for school wide change designed to enable all students to meet challenging State content and student academic achievement standards and addresses needs identified through a school needs assessment. (Cross, 2004, p.111)

An array of comprehensive school reform models, most often developed by external agencies, are implemented in urban elementary schools (Cross, 2004). During the 2010-2011 academic year, teachers participating in this study taught in elementary schools currently implementing the Core Knowledge, Direct Instruction, and International Baccalaureate reform models.

Context Beliefs

Context beliefs are beliefs about the responsiveness of one's environment regarding the attainment of a specific goal (Ford, 1992). In this study, elementary teachers' context beliefs represent teachers beliefs about the aspects of the school context enable effective science teaching and their beliefs about whether these aspects are likely to occur at their schools.

Elementary Science Education

Construed broadly, elementary science education refers to all aspects of teaching and learning of science within the elementary school context. The elements of elementary science education that will be focused on in this study include: science teaching practices, the allocation of time for science teaching, and the professional peer community of elementary science teachers.

Personal Agency Beliefs (PAB)

A composite of context and capability beliefs, personal agency beliefs are anticipatory evaluations about one's ability to attain a specific goal. This study examines both context and capability beliefs in order to profile elementary teachers' personal agency beliefs regarding their ability to effectively teach science within their local school contexts.

Resources

This study will use Knapp and Plecki's broad definition of resources for science teaching which includes: "the allocation of time within the day, week, and yearlong curriculum; access to natural world phenomena – and representations of them; the intellectual resources teachers bring to their work; and social resources residing in teachers' and learners' attitudes and beliefs toward learning, science, and each other" (pp. 1093- 1094).

Science Education Reform

A broad range of policies, initiatives, and programs intended to improve science teaching and learning. The primary vehicles for science education reform relevant to this study are State Science Standards and a district-wide Math/Science Initiative. A key aspect of science education reform is the promotion of inquiry oriented science teaching. This study uses the Reformed Teaching Observation Protocol (RTOP) and codes derived from the protocol to examine elementary teachers' observed and reported science teaching practices. See Appendix F for sample items from the RTOP instrument.

Teaching Policy Environment

The teaching policy environment is the context in which teachers' work as active, implementing agents. The teaching policy environment is characterized by the conditions that exist in individual schools as they interact with a wide variety of policies including: curriculum guidance (standards, curricular frameworks or materials at the school, district, state, and national levels); assessment and accountability policies; professional development and teacher support policies; and, workplace redesign and support policies. In this study, the teaching policy environment is operationalized by examining differences across the comprehensive school reform models implemented in the district. In the participating district, each school's comprehensive school reform model has implications for many of the polices enacted at the school level (e.g. accountability, assessment, curriculum); therefore, comprehensive school reform models are used as an index of each school's teaching policy environment.

CHAPTER 2: LITERATURE REVIEW

The literature review is organized into three sections. First, guided by the Knapp and Plecki (2001) framework, the review surveys scholarship on the influence of education policy and school and district contexts on elementary science education and reform. Second, the review summarizes research on comprehensive school reform, generally, and describes the Core Knowledge, Direct Instruction, and International Baccalaureate reform models. Finally, after a brief discussion of the nature of teachers' beliefs, the third section of the review describes previous studies examining teachers' personal agency beliefs as conceptualized by Ford's Motivational Systems Theory.

Search Methodology

Literature for this review was initially identified for inclusion by conducting a series of searches of ERIC (US Department of Education) and JSTOR databases. With the goal of locating material on elementary science education policy and reform, the initial search included the key words: *elementary science education reform and elementary science education policy.* Because searches for broad terms like *education reform, standards,* and *accountability* would return an unmanageable number of sources, searches on these terms were cross-referenced with searches for *science education* and *elementary science* to identify articles relating specifically to both elementary science education and major trends in education reform. Relevant research on comprehensive school reform was identified through searches with the key word *comprehensive school reform* as well as searches for work on the specific reform models included in the study : *Core Knowledge, Direct Instruction, and International Baccalaureate.* As Pajares (1992) notes, in the literature teacher beliefs often "travel in disguise" as a number of related constructs including: values, judgments, opinions, perceptions, conceptions, preconceptions, dispositions, practical knowledge, and perspectives (p. 309). Therefore, searches for the key terms *self-efficacy beliefs, capability beliefs,* and *personal agency beliefs* were supplemented with searches using various keywords including: *teacher beliefs, teacher perceptions, teacher practical knowledge, teacher intentions, teacher dispositions, and teacher conceptions.* Again, because searching these terms alone generated too many search results, they were cross-referenced with searches on terms specific to science education and science education reform. After literature was identified for review, I referred to bibliographies of each article to identify additional references.

Education Policy and Elementary Science Education Reform

This section of the review highlights relevant research on the implementation of science education reform and science teaching and learning in urban contexts. More specifically, this section presents research on three forces identified in Knapp and Plecki's framework (2001) as key drivers of events in urban science classrooms: interdependent school, district, and state policies; resource allocation; and, professional, organizational, and community context.

Interdependent School, District, and State Policies.

Although science education researchers are becoming increasingly interested in the opportunities, challenges, and risks that the current climate of education reform poses for elementary science education, empirical work in this area remains scarce. Appleton (2007) comments on this scarcity in a review of elementary science teaching included in the recent edition of the *Handbook of Research on Science Education*:

> I attend conferences such as AERA and NARST, where teachers recount horrific stories of curriculum limitation, dispirited teachers, and jaded students constrained by so-called reform high-stakes testing regimes; but little of this has actually been published … more research into the consequences of the reform initiatives on elementary science teaching and learning needs to be published. (p.505)

In spite of the paucity of research in this area, the work that does exist lends support to Knapp & Plecki's characterization of the teaching policy environment. There is little doubt that the various policy influences in the framework, from accountability policy to district professional development programs, do indeed "present opportunities and constraints, catalysts and barriers, incentives and disincentives" for science teaching and learning (Knapp & Plecki, 2001, p.1092). The challenge for education researchers is to clarify how policies within the teaching policy environment interact and what these interactions mean for teachers and students as they pursue the goals of science education reform.

The teaching policy environment is hierarchical in nature, with state policies nested within federal policies, district policies nested within state policies, and school policies nested within district policies. This hierarchy means that agents at each level must interpret policy that they themselves did not develop and integrate these policies with their existing goals and practices. In an effort to illuminate how district policy makers interpret state and federal policy, Spillane & Callahan (2000) explored responses to state science standards across nine Michigan school districts. Through interviews with district office administrators, district science specialists, principals, and teachers, the researchers found some interesting disconnects between the intentions of the state policy and the interpretations at the district and local levels. Although all of the districts appeared to attend to state standards, substantive changes in the science content and pedagogy were often lost in translation between the state and district levels. For example, only three of the nine districts made efforts to refocus the K-12 curriculum to reflect the goals of scientific inquiry and intellectually rigorous science at the core of the state's new standards. In describing reform efforts in their districts, participants were much more likely to use familiar terms to articulate their interpretations of the science reforms than they were to discuss the concepts that were central to the reforms. For instance, almost 83% of the participants used the term "hands-on" to describe state and national science reforms. Although the new standards emphasize constructivism and conceptual change approaches to science teaching and learning, only 13% of participants mentioned "constructivist learning" and less than half (45%) discussed improving students' conceptual understanding.

Other scholars have investigated the specific implications of the recent *No Child Left Behind Act* for science education. Cavanagh (2004) argues that the *No Child Left Behind Act* has prompted teachers to move away from hands-on, inquiry instruction in favor of direct instruction approaches to science teaching. Beginning in 2007, the federal law required districts to administer standardized tests in science and by 2014, to include student performance on science assessments in the calculation of Annual Yearly Progress (AYP). According to Cavanagh, these developments have forced schools to consider cutting back on the in-class science experiments and hands-on activities advocated by reform documents such as the *Benchmarks for Science Literacy* (AAAS,

1993) and the *National Science Education Standards* (NSES) (NRC, 1996). In spite of these potential changes in instruction brought about by the increased emphasis on standardized testing in science, Cavanagh (2007) notes the possibility that with increased accountability and testing, teachers could regain time for science instruction that had been lost due to a narrow focus on mathematics and literacy. Aronson and Miller (2007) further explore the tensions and challenges for science education embedded in the implementation of *No Child Left Behind*, arguing that there exists an imperfect alignment between inquiry-based instruction and the kinds of science learning assessed by the high-stakes assessments. An emphasis on test preparation, Aronson and Miller contend, could reduce instruction to a narrow set of discrete scientific facts that appear on assessments rather than fostering the creative and integrated approach to science teaching that is called for by the NSES.

Although empirical evidence documenting actual changes in science instruction as a result of *No Child Left Behind* and related policies is limited, researchers have investigated teachers' perceptions of the influence of standards, assessment, and accountability policy on science education. A recent study by Shaver, Cuevas, Lee & Avalos (2007) asked elementary school teachers how educational policies affected their science instruction. The study employed a questionnaire followed by focus group interviews with 43 third and fourth grade teachers from six elementary schools in a large urban school district. The results indicated that teachers' opinions concerning all areas of policy evolved as the state enforced stronger measures of accountability during the two-year period of the study. Although the teachers had relatively positive opinions regarding standards, their opinions about the effects of statewide assessment and accountability policies on science became increasingly negative. Shaver and colleagues describe teachers' perceptions of accountability policy, stating that "with one voice they complained about the insistence of their administrators that they teach to the test, emphasizing reading, writing, and mathematics, while reducing or even eliminating instruction in science and other subjects" (p. 734).

These results were consistent with a study by Pringle and Carrier Martin (2005) that explored the potential impact of impending standardized testing on science teaching in one urban district. The study surveyed elementary teachers' concerns about the upcoming high-stakes tests in science asked teachers to comment on what changes, if any, they expected in the approach to science teaching and learning in their classrooms. Teachers' concerns fell into five categories: concerns about the effects of poor reading skills on student performance, time constraints to include science lessons in the school day, too much emphasis being placed on standardized testing, teacher preparedness for science instruction, and lack of familiarity with the test format. The study found that as teachers looked toward increased testing in science, they renewed their commitment to teach science; however, this commitment was generally not based on a belief in the importance of science but rather on the effects of tangible rewards or punishments that accompany high stakes testing. The prediction of one veteran teacher is telling:

> Teachers will lose sight of the wonder and motivation that science can be to students. I am torn between being happy that science is finally being attended to by our district and feeling disappointed that we as educators are being motivated toward change by fear of a test (Pringle & Carrier Martin, 2005, p.8).

In anticipation of the new tests, the teachers participating in this study prepared to align their teaching to science standards while aggressively searching out test preparation materials. Recognizing that their study is limited by its focus on teachers' predictions and intentions regarding future reform, Pringle and Martin call for additional research that highlights how teachers' interpretations of standards are translated into teaching and learning activities.

In addition to widespread concern about individual policies (e.g. NCLB) or types of policy (e.g. accountability) directly impinging on science teaching, researchers have also emphasized the importance of coherence among the many policies that ultimately come to rest in elementary school classrooms (Hatch, 1997, 2002; Knapp, 1997; Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, Tal, 2004). Understanding the need for coherence requires an appreciation of just how busy teaching policy environments can be. Hatch (2002) reports that in a 1998-99 survey of school principals in the San Francisco Bay Area, 52% stated that their schools were implementing three or more programs or partnerships created by local groups and nationally known organizations and 15% reported implementing six or more different programs or partnerships. Follow-up surveys with comparison districts in California and Texas indicated that 63% of schools were involved with at least three programs and 27% were involved with six or more. One district reported that 18% of its schools were simultaneously implementing nine or more different programs. Hatch (1998) discusses the consequences of incoherence, asserting that:

> while many new practices, policies, and reform efforts may make sense in their own right, teachers and schools are frequently left to try to integrate and

> coordinate these varied initiatives when they have neither the resources nor the time to do their work well in the first place. (p. 626)

Knapp and Plecki define coherence within the science teaching policy environment as “the extent to which different strands of policy offer mutually supportive guidance for science teaching” (p. 1092). Given that policies often fail to provide such mutually supportive guidance, Knapp and Plecki contend that “the teaching policy environment often projects mixed messages about the importance of science and how it will be supported” (p.1092). Although the coherence of the teaching policy environment for science teaching has not been a major topic of research, one study investigating the effects of inquiry-based science education in urban elementary schools does illustrate the importance of coherence. Marx and colleagues (2004) report student learning data from a three-year-long science education collaboration with the Detroit Public Schools. The researchers collected student learning data from a district-wide sample of nearly 8,000 students who participated in curriculum units that emphasized inquiry and technology. The findings indicated statistically significant increases in curriculum-based assessments for each year of participation and increasing strength of the effects over the three-year implementation period. The researchers attribute the success of the reform, in large part, to coherence, stating that:

> reform programs that address the range of elements needed for coherence can succeed in urban settings. A combination of carefully designed curriculum materials, learning technologies that are embedded in the materials and serve the needs of learners, quality professional development, and policies that support reform are necessary. (p. 1075)

Resource Allocation

Knapp and Plecki define resources broadly, stating that "in their daily work teachers and students in conjunction with one another convert temporal, material, intellectual, and social resources into learning" (p. 1093). The resources thought to be of particular importance for science teaching include the allocation of time within the day, the week, and the school year; access to natural phenomena; teachers' intellectual resources (e.g. PCK); and, social resources characterized as "teachers' and learners' attitudes toward learning, science, and each other" (p. 1094).

A common refrain in the literature is that as districts and schools have focused on reform aimed at improving student achievement in reading, language arts, and mathematics, fewer resources have been devoted to elementary science education. Unfortunately, few studies have actually investigated investment in science at the school and district levels. One notable exception is a particularly revealing qualitative study examining the identification and allocation of resources for science education in urban elementary schools (Spillane, Diamond, Walker, Halverson, & Jita, 2001). A qualitative analysis of resource allocation across thirteen Chicago elementary schools revealed that investment in science was consistently limited relative to other subject areas. However, the study also found that it was not merely the presence or absence of resources but whether and how resources were identified and activated that accounted for differences in schools' commitment to science education. Within some schools, the devaluing of science education had come to be expected and was conceptualized by teachers and administrators as a "necessary evil" or simply as the "rules of the game." Not surprisingly, schools where this mindset about science education predominated were not likely to pursue innovation or improvement in science instruction in any serious way. On the other hand, in schools where teachers were invested in improving science education, limited resources were parlayed into substantive efforts to lead change in science education, even when science had not yet made it onto the school administrator's reform agenda.

Similar findings emerged from another study of urban schools' capacity to support change in mathematics and science (Gamoran, Anderson, Quiroz, Secada, Williams, Ashmann, 2003). This study analyzed the availability of resources across six "design collaboratives" comprised of urban schools in which teachers worked with researchers to improve their ability to teach for understanding in math and science. Similar to Knapp and Plecki and Spillane et al. (2001), the authors of this study define resources broadly to include material resources (e.g.: time and curricular materials), human resources (e.g.: expertise), and social resources (e.g.: professional collaboration). Over 60% of the teachers interviewed for the study named time as a valuable resource and the majority of these teachers noted that the best use of time was planning and learning with other teachers. The relative importance of time is evident in one teachers' comment that "money and verbal support from people around you is important, but I think in the long run if you don't have the time, you can't do it" (p. 68). Human resources found to be particularly important for the six collaboratives included the expertise of researchers who could help teachers build on their limited knowledge of student thinking. Although some schools reported having certain district or school leaders who were instrumental in their growth, the leadership of expert teachers was found to be even more consequential. Acknowledging the importance of coherence among social resources at the school and district levels, the researchers note that" outside expertise can have an impact only if it is perceived to be consistent with, or at least not opposed to, other district initiatives that affect the same teachers" (p. 73). In their analysis of the effect of colleagueship among teachers, the researchers found that professional development was enhanced by the presence of a strong existing colleague group. Interestingly, in addition to showing the many ways in which material, human, and social resources influenced professional development, the researchers also found evidence that professional development influenced the availability of resources. In addition to fostering increases in the expertise and the development of stronger colleagueship among participants, at some sites, the professional development initiative improved the availability of material resources. For example, teachers who participated in the program created curriculum materials that could be circulated among sites. The authors also note that the professional development created incentives for continuing the collaboration, either by generating additional resources or reallocating existing resources.

Professional, Organizational, and Community Context

Knapp and Plecki contend that the actualization of resources is mediated by professional, organizational, and community contexts. Examples of context mediating efforts to improve science education are evident in the previous discussions of interdependent policies and resource allocation. For example, Spillane et al. (2001) and Gamoran et al.'s (2003) studies of resource allocation suggest that teachers' commitment to science teaching and learning was dependent not only on the availability of resources but also on whether schools' had strong professional peer communities dedicated to science education. Indeed, numerous studies have found that teachers' ability to translate policy into practice can be constrained by a number of external contextual factors (Pedretti & Hodson, 1995; Abell & Roth, 1992; Cornbleth, 2001).

Pedretti and Hodson (1995) conducted a study on implementing Science Technology and Society (STS) programs through action research and concluded that working directly with teachers may not be enough to significantly impact the implementation of the STS curriculum. The authors contend that contextual factors such as the structure of the school system including its bureaucracy, administrative procedures, and values can encourage traditional approaches to teaching and, consequently, compromise meaningful science learning. Similarly, Cornbleth (2001) describes how school climate can constrain teachers as they work to implement new curricula or change their teaching practice. More specifically, Cornbleth notes that bureaucratic school climates often foster a "law and order" climate in which following school-wide rules (e.g. attendance, dress codes, grading) and maintaining clean, quiet classrooms take precedence over intellectual risk-taking and inquiry at the heart of science education reform.

In summary, science education reform, like any effort to foster educational change, does not occur in isolation. Interdependent policies, resource allocation, and professional, organizational, and community contexts all have implications for whether and how elementary teachers are empowered and motivated to teach science. Just as these factors help explain teachers' beliefs about science education and reform, teachers' beliefs may also help us better understand the complexities of local policy implementation. This prospect is well articulated by Nespor (1987), who stated that "the contexts and environments within which teachers work, and many of the problems they encounter, are ill-defined and deeply entangled … beliefs are peculiarly suited for making sense of such contexts" (p. 324). Of particular interest for the current study is the relationship between the teaching policy environment and teachers' beliefs about their ability to work as agents of reform.

Comprehensive School Reform

Having provided an overview of research on the effects of education policy on science education, this section of the review focuses on describing the major features of comprehensive reform as an approach to school improvement and on detailing the three comprehensive school reform models included in this study.

What is Comprehensive School Reform?

One way that schools have attempted to address the problem of incoherence is through the adoption of "whole-school" reform programs. Specifically, the Comprehensive School Reform Demonstration program, authorized by Congress in 1997, provided $145 million for schools to implement "comprehensive" school reform models (Cross, 2004). These models, developed either by an external organization or locally by individual districts and schools, are intended to foster coherence by integrating all aspects of school functioning including instruction, assessment, classroom management, professional development, parental involvement and school management. Although the definition of "comprehensive school reform" included in the federal legislation explicitly states that such programs should include all subject areas, many popular school reform models (e.g. Direct Instruction, Success For All, Core Knowledge) tend to focus on reading, language arts, and mathematics (Northwest Regional Educational Laboratory, 2006). Further, as noted, the extent to which comprehensive school reform models are designed to permit the type of inquiry-based science instruction called by science education reformers remains unclear. To date, there have been no studies examining the specific effects of comprehensive school reform programs on elementary science education. Studies evaluating comprehensive school reform initiatives often focus on outcomes in reading, language arts, and mathematics while paying little attention to achievement in science. For example, in their meta-analysis of studies evaluating 29 nationally implemented comprehensive school reform (CSR) models, Borman, Hewes, Overman, and Brown (2003) rank reform models according to whether they have "strong evidence of effectiveness" and conclude that, overall, the effects of CSR on student achievement are promising (p. 31). However, taken together, the 232 studies compiled for the meta-analysis included far more independent samples for reading (1,017) and math (679) achievement than they did for either science (229) or social studies (138). Additionally, it should be noted that two of the three reform models designated as having "strong evidence of effectiveness," Direct Instruction and Success For All, emphasize reading and, to a lesser extent, mathematics, but generally do not include a science education component.

Perhaps most disconcerting, many of the most widely implemented comprehensive school reform models are grounded in philosophies of teaching and learning that conflict with the modes of teaching and learning advocated by science education reformers (Duschl et al. , 2007). Although a thorough exploration of these conflicts would be beyond the scope of this paper, examining the Core Knowledge, Direct Instruction, and International Baccalaureate reform model begin to illustrate the tensions that can exist between comprehensive school reform models and elementary science education.

Core Knowledge

The Core Knowledge reform model derives from E.D. Hirsch's experiences as a professor of English and education, and focuses almost entirely on defining a "common core" of knowledge within various subject areas including literature, history, science, mathematics, and the arts. The model is designed so that students build on knowledge from year to year in grades K-6 (Datnow, Borman, & Stringfield, 2000). According to the Core Knowledge Foundation, the sequence is intended to provide 50% of the content taught in a U.S. elementary school. The model was pilot tested at a Florida elementary school in 1990. During the 2009-2010 school year the Core Knowledge reform model was implemented in 770 schools in 46 states. The model has been implemented in various types of schools – currently, 40% of Core Knowledge Schools are public schools, 38% are charter schools, and %16 are private schools. Of official Core Knowledge schools, 46% are in urban settings, 36% are in suburban settings, and 18% are in rural settings.

Hirsch first described the thesis behind the Core Knowledge curriculum in his controversial publication, *Cultural Literacy* (1987), which included an appendix listing "what every American should now." The book was widely critiqued for promoting arbitrary, elitist forms of knowledge and for treating "curriculum as the repository of society's dominant values about worthwhile knowledge" (Elmore & Sykes, 1992, p. 208). In response to his critics, Hirsch assembled a board of advisors including experts in multiculturalism and consulted an independent group of educators, scholars, and scientists to attempt to draft a list of topics for grades K-6 that reflected diverse perspectives. The list ultimately became the Core Knowledge Sequence. The Core

Knowledge Foundation insists that "Core Knowledge is an anti-elitist idea. It aims to guarantee equal access for all to the knowledge necessary for higher literacy and learning". However, critics have continued to argue that Core Knowledge is a right-wing movement that "poses serious threats to social order already unjust and unequal (Buras, 1999, p. 91) and preventing debate about the dominant perspective (Oakes & Lipton, 1999). Hirsch's model has since been popularized through the publication of a series of texts, which, according to their titles, prescribe *What Your [1st – 6th grader] Needs to Know* about various subject areas.

The research base for the Core Knowledge reform model includes mixed results regarding the model's effect on student achievement. One mixed-methods study (Datnow, Borman, & Stringfield, 2000) found that although they scored significantly higher than control students on tests of Core Knowledge content, students' in schools implementing the Core Knowledge reform model had standardized test scores that were about the same, or slightly better than, demographically matched control students. Interestingly, although Hirch (1996) explicitly argues against progressive teaching methods, Datnow and colleagues found that in the schools they studied Core Knowledge was associated with more hands-on, activity-based instruction. The authors discuss this discontinuity, stating that:

Ironically, the implementation of Core Knowledge led schools away from these traditional methods and toward the progressive methods that Hirsch criticizes. This was largely because teachers found that getting students to understand complex topics required diverse instructional methods, most notably, experiential learning (p. 183).

Additionally, teachers and principles reported that Core Knowledge was seen as a vehicle for integrating subjects across the curriculum. The study also noted that there was little resistance to the Core Knowledge model among teachers and described several ways in which the model appeared to improve teachers' professional lives, including promoting collegiality and allowing for teacher autonomy and individual teaching styles. At the same time, teachers noted that the Core Knowledge model required intensive planning and collaboration. Finally, despite intense debate among educational researchers regarding the politics of Core Knowledge (e.g., Buras, 1999; Feinberg, 1997), Datnow, Borman, and Stringfield (2000) found that educators tended to resist the politics surrounding the reform and engaged in relatively little discussion about what topics to include, emphasize, or remove from the Core sequence.

In his review of CSR implementation research, Cross (2004) classifies the Core Knowledge model as a less comprehensive model, in that it tends to focus on changes in the curriculum, but little else. According to Cross, whereas certain models (e.g. Accelerated Schools, the Comer School Development program, Direct Instruction) seek to change organizational processes, instruction, assessment, and staffing, among other elements of school functioning, Core Knowledge is an example of a model that provides minimal guidance about changes to instructional practice or school organization and management.

Although E.D. Hirsch's Core Knowledge movement may be less prescriptive than programs like Direct Instruction when it comes to science teaching and learning, the program's approach to teaching and learning may still be problematic. As Kristen Buras' critical analysis (2008) reveals, Hirsch's Core Knowledge program is predicated on the notion that education is fundamentally a process aimed at the transmission of factual content. According to Hirsch's address to teachers at a 2004 Core Knowledge national meeting, "the Core Knowledge movement is based on deep principles that really have been established by the best scientists" (cited in Buras, 2008). Buras describes Hirsch's invocation of cognitive research stating that:

> He sees education as a cognitive-technical process through which factual content is transmitted to students for storage in memory. Using cognitive psychology and neurophysiology, or what Hirsch terms 'consensus research,' as a basis for his educational theory, he asserts that excellence in schooling necessitates an appreciation of the centrality of short-and long-term memory, repetition and automation, development of mental schemas consisting of vocabulary and specific facts, and the continuous acquisition, chunking, assimilation, and stocking of new information in an accurate fashion. (p. 47)

Buras goes on to critique this cognitive-technical perspective, drawing our attention to the ways in which it enables Hirsch to deny the political nature of education, rendering the content and processes of learning uncontroversial and unproblematic. I'd like to extend Buras's critique to suggest that the problem is not merely the fact that Hirsch draws upon cognitive research to substantiate his vision of teaching and learning, but rather that he does so *selectively*, imagining the existence of "consensus research" and ignoring entire traditions of cognitive research that plainly contradict the tenets of Core Knowledge.

Hirsch's misapplication of scientific evidence and the falsehood of his "consensus research" become abundantly clear in light of cognitive research on the structure and development of children's scientific knowledge. A recent publication by the National Research Council (NRC) entitled Taking Science to School: Learning and Teaching Science in Grades K-8 (Duschl et al., 2007) "brings together research literatures from cognitive and developmental psychology, science education, and the history and philosophy of science to synthesize what is known about how children in grades K-8 learn the ideas and practice of science" (p. vii). This synthesis yields conclusions about science learning that stand in stark contrast to Hirsch's interpretation of cognitive research. For example, whereas Hirsch underestimates and minimizes the importance of students' prior knowledge and experience, the NRC report concludes that "children entering school already have substantial knowledge of the natural world, much of which is implicit", that "students' knowledge and experience play a critical role in their science learning", and that "race and ethnicity, language, culture, gender, and socioeconomic status are among the factors that influence the knowledge and experience children bring to the classroom" (p. 2-3). The NRC report directly refutes Hirsch's argument that students must possess a "great deal of solid knowledge" before they are prepared to engage in critical thinking (cited in Buras, 2008, p. 49):

> The commonly held view that young children are concrete and simplistic thinkers is outmoded; research shows that children's thinking is surprisingly sophisticated. Yet much current science education is based on the old assumptions and so focuses on what children cannot do rather than what they can do. Children can use a wide range of reasoning processes that form the underpinnings of scientific thinking. (p.3)

Finally, with regard to the metacognition Hirsch finds so problematic, the report finds that “the instructional techniques that have been shown to be effective in producing conceptual understanding of new science content all have a strong metacognitive component” (p. 112).

Given the available evidence on science learning, the publication offers a framework for proficiency in science that acknowledges that “content and process are inextricably linked in science” and suggests that students who are proficient in science:

> know, use, and interpret scientific explanations of the natural world, generate and evaluate scientific evidence and explanation, understand the nature and development of scientific knowledge, participate productively in scientific practices and discourses (p.3).

Note that while this framework does not necessarily preclude the acquisition of the science “facts” that may appear in the Core Knowledge curricula, it invites even young children to engage in science at a level of rigor that Hirsch would seem to reserve for advanced students or “professional” scientists. Thus, any “research consensus” regarding either children’s science learning or the modes of science education they imply clearly does not side with E.D. Hirsch.

Direct Instruction

Initially developed by Siegfried Engelmann in the 1960s, Direct Instruction applies behaviorist learning theory to classroom instruction. Much like the animals in B.F. Skinner’s laboratory, the learning and behavior of students in a D.I. classroom are regulated through a repetitive, teacher-directed stimulus-response cycle. The National

Institute for Direct Instruction (NIFDI), which oversees the implementation of direction instruction, describes the program as:

a model for teaching that emphasizes well-developed and carefully planned lessons designed around small learning increments and clearly defined and prescribed teaching tasks. It is based on the theory that clear instruction eliminating misinterpretations can greatly improve and accelerate learning ("http://www.nifdi.org/index.html#what%20is" http://www.nifdi.org/index.html#what%20is).

In practice, “carefully planned lessons,” “clearly defined and prescribed teaching tasks,” and “clear instruction eliminating misinterpretations” amount to traditional, teacher-directed instruction. Adams and Engelmann (1996) describe the Direct Instruction approach to teaching as follows:

> To teach effectively, a teacher must present specific examples of what is being taught and must say something about them…Direct Instruction programs assist teachers by specifying good examples, with short and efficient wording for each example, and by arranging the examples in an effective sequence. The teacher must still teach: present the examples; execute the wording; and most importantly, respond to students by reinforcing correct responses and providing corrections and repetition of items the students miss (p.3).

In a typical reading lesson, the teacher introduces a new word or sound (“This word is cat”), asks a question (“What word”?), gives a verbal signal (often “Get Ready” accompanied by a finger snap, or in some cases the click of a dog-training device), and students repeat the answer back to the teacher in unison (“cat”). At this point, depending on the students’ performance, the teacher either offers positive reinforcement (“yes, cat") or a correction ("no. This word is cat.") This sequence is repeated within lessons until all students are "firm" on a particular item and reinforced by review of each item across many lessons.

Proponents of Direct Instruction cite studies in which students in Direct Instruction programs outperform students in other reform models. For example, in their meta-analysis of 37 studies on Direct Instruction, Adams and Engelmann (1994) concluded that of 173 individual comparisons of student performance in Direct Instruction and Non-Direct Instruction groups, the Direct Instruction group performed better than Non-Direct Instruction group 151 times (87.3% of the time). Although the Adams and Engelmann (1994) do not report study results by subject area, their conclusion that "the DI students excelled in all subjects – reading, arithmetic, spelling, and language" (p.4) betrays the fact that science, as a subject area, is generally not prioritized by the Direct Instruction model.

At first glance, Direct Instruction may appear to serve primarily as a curriculum and approach to instruction in Reading, Language Arts, and, in some cases, Mathematics. However, as a Comprehensive School Reform Model, Direct Instruction influences nearly every aspect of school functioning, from scheduling to classroom management to resource allocation to teacher professional development. For example, according to the National Institute for Direct Instruction, principals and teachers involved in implementing the Direct Instruction reform model should agree to consistent daily schedules, a set curriculum with no conflicting elements, specific grouping and management procedures, and a three-to-five-year timetable for implementing all programs and procedures in all grades with all students. NIFDI also states that teachers should commit to attending scheduled professional development sessions and must agree to ongoing classroom monitoring (http://www.nifdi.org/index.html#what%20is).

Although Direct Instruction is not generally prescribed as an instructional program in science, the program's behaviorist foundation and implementation model have clear implications for science in the elementary classroom. First, rigid, repetitive instruction is time-consuming, with Direct Instruction lessons in literacy commonly consuming up to three hours of each school day (http://www.nifdi.org/index.html#what%20is). When instructional time for other core subject areas (mathematics, language arts, writing) along with regular school day activities (lunch, restroom breaks, assemblies) is accounted for, time for science (and social studies) in Direct Instruction schools becomes scarce. This scarcity is only compounded by the fact that the program's script does not permit any meaningful integration of science and literacy or science and mathematics, a strategy that elementary teachers have found promising as dedicated science time has been stripped from school schedules (Lundstrom, 2005). Second, and perhaps even more problematic for science education, behaviorist instruction has little to offer when it comes to fostering students' conceptual development in science. Given the recommendations for science teaching and the processes of science learning emphasized in recent science education reform documents (e.g. Duschl et al. , 2007), fostering science learning in a Direct Instruction classroom would require teachers to negotiate discrepant visions of the ways teachers and students ought to engage with each other, their classroom environment, and the curriculum.

International Baccalaureate

Founded in 1968, the International Baccalaureate (IB) is an international education organization headquartered in Geneva, Switzerland. International Baccalaureate programs are currently implemented in 3,072 schools in 139 countries (www.ibo.org). In recent years, the number of U.S. schools implementing the IB program has grown exponentially, from 88 in 1997 to 797 in 2007. Ninety percent of the IB programs offered in the United States are in public schools and 30% are in Title 1 schools in which the majority of students are classified as economically disadvantaged (Cech, 2007).

The stated mission of the IB organization is to "help develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect" (IBO, 2010, para. 3). To this end, IB offers curricula frameworks and three educational programs for students ages 3 – 19. The IB Diploma program, which is intended for high school students age 16- 19, provides internationally standardized courses and assessments and is intended to "provide an internationally acceptable university admissions qualification suitable for the growing mobile population of young people whose parents were part of the world of diplomacy, international and multi-national organizations" (Fox, 2001, p.65). The International Baccalaureate's Middle Years Program was developed for students' aged approximately 11 – 16 and includes eight subject areas: humanities, sciences, mathematics, arts, physical education, technology, and two language courses. Within five years of initial pilot testing in the mid-1990s, the Middle Years program was implemented in 51 countries (Peterson, 2003, p. 243). The Primary years Program for students ages 3 - 11 was pilot tested in 1996 in thirty elementary schools on different continents. Within five years of the 1997 authorization of the first Primary Years Program, the program was implemented in as many as 87 schools in 43 countries (Peterson, 2003, p. 246). There are currently 173 elementary schools implementing the IB Primary Years Program in the United States.

Unlike the Core Knowledge and Direct Instruction reform models, the International Baccalaureate program emphasizes inquiry , taking an interdisciplinary approach that defines its curriculum as fulfilling “the need to acquire skills in context, and to explore content that is relevant to students and that transcends the boundaries of the traditional subjects” (IBO, 2008, p. 7). The program also makes explicit the importance of building on the knowledge and experience students bring to the classroom, stating that “the Primary Years Program is based on the principle that children learn by using their previous experience to make sense of new information” (IBO, 2002, p.6). Accordingly, the Primary Years Program features a curriculum framework in which teachers collaborate to design units based on six transdisciplinary themes: who we are, where we are in place and time, how we express ourselves, how the world works, how we organize ourselves, and sharing the planet. In designing inquiry activities, teachers’ draw from content within six subject areas: language, social studies, mathematics, arts, science, personal, social and physical education.

The Primary Years Program curriculum framework supplements the transdisciplinary themes with five essential elements - concepts, knowledge, skills, attitudes, and action - that define the learning opportunities that should be made available to all students. According to these elements, all students participating in the IB Primary Years Program should “gain knowledge that is relevant and of global significance, develop an understanding of concepts, acquire transdisciplinary and disciplinary skills, develop attitudes that will lead to international-mindedness, and take action as a consequence of their learning" (www.ibo.org).

In addition to the curriculum framework particular to the IB Primary Years Program, the program articulates its mission in terms of an IB Learner Profile comprised of specific traits that should be cultivated throughout a student's lifelong education. The Learner Profile describes an ideal in which IB students strive to become inquirers, knowledgeable, thinkers, communicators, principled, open-minded, caring, risk-takers, balanced, and reflective. The programs' conceptualization of each of these Learner Profile traits is provided in Appendix A.

The IB Primary Years Program's philosophy and curriculum framework clearly prioritize student inquiry and would seem to align with many of the recommendations of science education reformers, perhaps because the Primary Years Program is still relatively new, little work has examined the outcomes of the program for science education. One notable exception is a recent qualitative study by Twigg (2010) that investigated the practices, values and beliefs of elementary teachers at one independent International School in Europe. The eleven teachers who participated in the study were currently in the process of transitioning from a traditional didactic approach to an inquiry-based approach with the implementation of the IB Primary Years Program. Through analysis of teacher responses on questionnaires and teacher narratives, Twigg (2010) found that as teachers implemented the Primary Years Program, they began to envision learning as a shared responsibility between students and teachers and to place more value on children's contributions to the inquiry process. The study also found that a collaborative professional community in which teachers worked together to plan, implement, and reflect on practice tended to facilitate teachers' transition from traditional teaching methods to inquiry-based methods.

Of particular relevance for the current study, is a recent dissertation study by May (2009) that examined inquiry-based instruction in one Georgia elementary school implementing the IB Primary Years Program. Through observations, interviews, and the analysis of documents, the study explored inquiry among students and teachers at the school as well as the conditions that influence inquiry at the school and classroom levels. Although the study did not look specifically at science lessons, May found evidence in the majority of classrooms that students were engaged in inquiry that involved authentic problems, generating questions, conducting research, and reserving time and freedom for reflection. The study also found that, in the process of implementing the Primary Years Program, teachers at the school site and across IB schools worked collaboratively to solve authentic problems and to reflect on their practice. Interestingly, one of the major challenges the school faced was integrating the curriculum framework with the IB Primary Years Program with the Georgia Performance Standards. Although devising units and lesson plans that met the requirements of both the IB Primary Years Program curriculum framework and the Georgia Performance standards proved to be a challenging and time-consuming task for the teachers, May (2009) reports that the curriculum framework appears to be flexible enough to accommodate the standards. Consistent with previous research on the effects of school reform policy on elementary science teaching (Pringle & Carrier-Martin, 2005; Tate, 2001) teachers cited limitations on time and the prioritization of high-stakes testing as factors that impinged on their ability to engage students in inquiry activities.

This overview of the Direct Instruction, Core Knowledge, and International Baccalaureate reform models reveals clear differences in each program's approaches to teaching and learning, in general, and important implications for the teaching and learning of science, in particular. The three reform models appear to provide varying levels of support for science education, both materially and philosophically. The Direct Instruction model seems to neglect science altogether and promotes teacher-directed, behaviorist methods that conflict with the processes of inquiry and conceptual development that underlie science learning. The Core Knowledge model prescribes discrete science facts that all students should know without attending to practice of science teaching and learning. In contrast, the International Baccalaureate model explicitly prioritizes inquiry and includes science as a core subject area within its transdisciplinary curriculum framework. Although one can imagine that these reform models could inculcate vastly different approaches to science education, the ways in which the philosophies and assumptions about teaching and learning imbedded within each of these school reform models manifest and interact with science education at the school and classroom levels remains unclear. Given the prominence of comprehensive school reform models in elementary schools across the nation, it will be imperative for researchers interested in clarifying the relationship between education policy and science education reform to look more closely at whether and how CSR models support the goals of science education reform.

The Nature of Teachers' Beliefs

In his oft cited review, Pajares (1992) calls teacher beliefs a "messy construct," and for good reason. According to Pajares, the difficulty in studying teacher beliefs stems from "definitional problems, poor conceptualization, and differing understandings of belief structures" (p.307). Science education researchers, having done their part to "mess up" the teacher beliefs construct, are not immune to this difficulty. A survey of the science education literature reveals teacher beliefs as a sort of moving target, continually defying consistent definition or application. Consequently, examining previous research on elementary teachers beliefs about science education and reform requires first considering the nature of beliefs and the variety of definitions in circulation.

Although there is no simple answer to the question "What is a belief?," Pajares reviews the definitions proposed by a number of theorists. Pajares tells us that these definitions include Sigel's assertion that beliefs are "mental constructions of experience - often condensed and integrated into schemata or concepts" (cited in Pajares, 1992, p. 351). Similarly, Nisbett & Ross describe beliefs as "reasonably explicit propositions about the characteristics of objects and object classes" (p. 351). Brown and Cooney (cited in Pajares, 1992) emphasize the relationship between beliefs and action, stating that beliefs are "dispositions to action," which are both time- and context-specific. Rokeach (cited in Pajares, 1992) offers what may be the most encompassing and, as Pajares notes, circular definition of beliefs as "any simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded by the phrase, 'I believe that …" (p. 352).

In spite of this diversity of definitions, certain elements are shared across the various conceptualizations of teacher beliefs. Common propositions among the various definitions include the notion that beliefs are personal constructs, that they are not always logical, and that they are not consensus driven. According to Pajares, beliefs are differentiated from knowledge because they are based on subjective judgments rather than objective facts. At the same time, Loucks-Horsley et al. (1998) assert that "beliefs are more than opinions: they may be less than ideal truth, but we are committed to them" (p. 27).

Given the elusive nature of teachers' beliefs, Pajares argues that in order to be useful, the overarching construct of teachers' beliefs, like all broad psychological constructs, must "come before the reductionist, multidimensional, or hierarchical chopping block to better suit the needs and requirements of research" (p. 315). Accordingly, Pajares advises researchers that "*educational beliefs about* are required" (p.316). That is, when studying teachers' beliefs, it is necessary to specify the particular type of beliefs under investigation - to note first that the research concerns teachers' *educational beliefs,* rather than their general belief-systems, and to further designate what the targeted educational beliefs are about. With this advice in mind, the following sections review research focusing on elementary teachers' beliefs about their ability to achieve the goals of science education reform (i.e. personal agency beliefs).

Personal Agency Beliefs

In their attempts to identify factors that motivate people to achieve particular goals, theorists have reserved a special role for beliefs (Maslow, 1943; Deci & Ryan, 1985; Bandura, 1986). Many researchers have investigated teachers' self-efficacy, defined by Bandura (1986) as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.391) (e.g. Tobin, Tippins, &

Gallard, 1994). Bandura (1997) comments on the need to examine teachers' science self-efficacy stating that ''teacher efficacy in science education is of particular concern, given the increasing importance of scientific literacy and competency in the technological transformations occurring in society (p. 242).'' This line of research has provided strong evidence that self-efficacy is related to successful science teaching (Tobin, Tippins, & Gallard, 1994; Czerniak & Shriver, 1994) and that increasing self-efficacy could empower teachers to work more purposefully toward their goals (Roberts, Henson, Tharp, & Moreno, 2001). For example, Czerniak and Shriver (1994) found that pre-service science teachers with high self-efficacy tended to use a variety of instructional strategies, in contrast to teachers with low-self efficacy, who relied primarily on the textbook. Similarly, through the analysis of teaching videos, Riggs, Enochs, and Posnanski (1991) found that teachers with high self-efficacy and high expectations for their teaching outcomes covered science content and skills more thoroughly, asked more open-ended questions, checked more frequently for student understanding, and connected content to students' lives more often than teachers with low-self efficacy.

In considering factors that may motivate elementary teachers to teach science, it is imperative to recognize that teachers' beliefs, in general, and their self-efficacy beliefs, in particular, do not exist in isolation but in relation to teachers' other belief structures and the real world teaching context. As Pajares (1992) notes, Bandura acknowledged that "self-efficacy, a belief sub-construct, is too broad, vague and context free to be useful" and that "self-beliefs must be context specific and relevant to the behavior under investigation to be useful to researchers and appropriate for empirical study" (p.315).

Indeed, studies have demonstrated a relationship between contextual factors and teachers' self-efficacy for science teaching. For example, Ramey-Gassert, Shroyer, and Staver (1996) examined factors associated with elementary teachers' science teaching efficacy. The researchers found that teachers' science teaching self-efficacy was related not only to antecedent factors (previous science experience, teacher preparation, science teaching experiences) and internal factors (attitudes toward and interest in science), but also to a number of external factors including the school workplace environment, student variables, and community variables.

Ford's Motivational Systems Theory (1992) synthesizes existing motivation theories to provide a framework for examining individuals' capability beliefs (synonymous with Bandura's self-efficacy beliefs) in conjunction with their beliefs about their context. Ford argues that capability and context beliefs combine to form personal agency beliefs, defined as anticipatory evaluations about one's ability to attain a specific goal. Ford theorizes that such judgments reflect both our beliefs about our own capability and our beliefs about the responsiveness of our environment. Within this framework, it is possible for individuals to believe very highly of their own capability but doubt their ability to achieve a specific goal because they also believe that their environment is not responsive to their needs. Conversely, an individual with doubts about their own capability may judge that a responsive environment could enable them to realize their goals. Ford's taxonomy theorizes the following ten possible personal agency belief (PAB) patterns: Robust, Modest, Fragile, Tenacious, Vulnerable, Self-doubting, Accepting, Antagonistic, Discouraged, and Hopeless. (See Ford, 1992 for a discussion of each of these personal agency belief patterns).

In my review of the literature, I identified four studies (Lumpe, Haney, Czerniak, 2000; Haney, Lumpe, Czerniak, & Egan, 2002; Andersen, Dragsted, Evans, & Sorensen, 2004, and Bhattacharyya, Volk, & Lumpe, 2009) that examine personal agency beliefs for science teaching. Each of these studies is reviewed below.

In the first study, Lumpe, Haney, and Czerniak (2000) employ Ford's Motivational Systems Theory to develop a measure of teachers' beliefs about their science teaching context. The resulting Context Beliefs about Teaching Science (CBATS) instrument includes 26 items (rated on a five point scale) and is designed to measure a) teachers' beliefs about the degree to which certain environmental factors would enable effective science teaching and b) teachers' beliefs about the likelihood of each factor occurring in their schools. The authors propose that the CBATS could be used in conjunction with existing science teacher self-efficacy measures, such as the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs & Enochs, 1990), to construct profiles of teachers' personal agency belief patterns.

In their efforts to validate the CBATS instrument, Lumpe et al. surveyed a sample of 262 K-12 teachers. In addition to providing evidence for the construct and content validity of the CBATS, the researchers found that most of the teachers they surveyed displayed either robust or tenacious PAB patterns. A robust PAB pattern is, according to Ford, the "most motivationally powerful…because people with strong capability beliefs and positive context beliefs maintain the expectation that their goals will be achieved in the face of obstacles, difficulties, and failures" (pp. 134 - 135). A tenacious pattern, suggested by strong capability beliefs and neutral or variable context beliefs, is indicative of "strength in dealing with obstacles and challenges" (p. 134).

Although teachers with a tenacious pattern have confidence in their own capabilities, they may doubt the responsiveness of their environment. Other teachers in the sample exhibited either vulnerable or modest PAB patterns. A teacher with a vulnerable pattern could be "functioning adequately, but may be at risk under conditions of stress" (p. 134). The authors suggest that "vulnerable patterns could be counterproductive to educational change processes" and that "it is likely that teachers who display vulnerable patterns may adopt an accepting/antagonistic or self-doubting pattern if either their capability or context beliefs are further hindered" (Lumpe et al., 2000, p. 287).

Haney, Lumpe, Czerniak, & Egan (2002) subsequently conducted a study that examined the relationship between the personal agency belief patterns and the science teaching practices of six elementary teachers. To assess the effectiveness of the science teaching, the study used a protocol developed by Horizon Research, Inc. for the purpose of evaluating National Science Foundation local systemic change initiatives. The CBATS and STEBI instruments were used to measure context and capability beliefs, respectively. Using the guidelines described in their previous study, the authors used both measures to classify the teachers' personal agency belief patterns. Additional qualitative data, gathered through open-ended interviews, was used to provide further evidence regarding the teachers' personal agency beliefs.

Among the six teachers in the study, two were classified as having a vulnerable personal agency belief pattern, two were classified as having a tenacious pattern, and two were classified as having a robust pattern. The researchers found that three of the four teachers who possessed robust and tenacious personal agency belief patterns exhibited effective science teaching practices. Specifically, the authors note that these teachers tended to deliver science lessons that: illustrated careful planning, incorporated inquiry, drew on students' prior knowledge and experiences, were sensitive to issues of equity, encouraged collaboration, and utilized available resources. One robust teacher, who conveyed extremely strong capability beliefs and positive context beliefs during the interview process, had substantial problems with implementation, content knowledge, and classroom environment. As predicted, each of the teachers with vulnerable personal agency belief patterns scored low on the observation protocol, also exhibiting substantial problems with the implementation and content of their lessons. The authors conclude that their findings provide support for the view that beliefs are valid predictors of teachers' actions. The authors also discuss possible explanations for the discontinuity between one teachers' robust personal agency beliefs and her poor teaching practices. These explanations include the possibility that the teachers' performance was underrated by the observer, the possibility that the teacher dramatically overestimated her capability and the possibility that the teachers' beliefs about what constitutes effective science teaching did not align with the definition of the effective teaching that informed the observation protocol.

Andersen, Dragsted, Evans, & Sorensen, (2004) conducted a similar study looking at the capability and context beliefs of a cohort of new elementary teachers in Denmark. The researchers used a modified version of the STEBI instrument (the STEBI-DK) to measure self-efficacy three times over the course of the first year of teaching. The survey sample included 66 teachers for the first STEBI-DK administration, dropped to 49 teachers for the second and to 39 for the third. Context beliefs were measured once using the CBATS instrument along with the final administration of the

STEBI-DK. The researchers found that the teachers' self-efficacy ratings dropped significantly between the first and second administrations of the STEBI-DK ($p < .02$) but remained stable between the middle and end of the first year of teaching. Examining the relationship between these changes in self-efficacy and teachers' ratings of their school environments, positive changes in self-efficacy were related to higher ratings on both the likelihood ($r = .401$, $p = .011$) and enable ($r = .556$, $p = .00$) scales of the CBATS instrument. The combined likelihood and enable CBATS scores were also significantly related to high self-efficacy changes during the year ($r = .556$, $p = .00$). That is, teachers whose self-efficacy increased tended to believe that the environmental factors on the CBATS would enable them to be effective science teachers and that these factors were likely to occur at their schools.

These findings were further illustrated through three case studies with participants chosen based on their initial self-efficacy scores. The researchers selected two teachers with average self-efficacy scores and one teacher with an initial high self-efficacy score. The teacher with the high initial self-efficacy score had an average score on the CBATS likelihood scale, indicating moderate likelihood that favorable teaching conditions would be present at her school. This teachers' self-efficacy score dropped considerably between the beginning and middle of the school year and again between the middle and end of the school year. Given this falling self-efficacy score and the negative perception of the school environment portrayed in interviews, the authors believed that this teacher would fall into the vulnerable category in Ford's taxonomy of personal agency beliefs. The other two teachers reported relatively high CBATS likelihood scores and either increasing or stable self-efficacies throughout the year.

Based on these patterns and qualitative data gathered through interviews, the authors concluded that one of these teachers exemplified Ford's robust personal agency belief pattern and one was on the border between the robust and vulnerable patterns. As in Haney et al.'s study, the authors used the Horizon's observation protocol and found that these three teachers' personal agency belief patterns corresponded to the effectiveness of their science teaching practices. That is, the two teachers with the more robust patterns were rated as more effective than the teacher with the vulnerable personal agency belief pattern.

Bhattacharyya, Volk, and Lumpe (2009) examined the effects of an extensive inquiry-based field experience on pre-service elementary teachers' personal agency beliefs. The study compared changes in personal agency beliefs among 14 elementary teachers who self-selected into two groups: an experimental group that implemented inquiry methods and a control group that used traditional teaching methods. As in Haney et al. (2002) and Andersen et al. (2004) studies, the participants completed the CBATS and a version of the STEBI (STEBI-B for preservice teachers). The researchers found that, in general, the PAB patterns of the control group declined and the PAB patterns of the experimental group increased. This difference between the experimental and control groups' PAB patterns was attributed to the possibility that the inquiry method could have boosted the teachers' capability beliefs; however, the authors caution that the result could also reflect the fact that the experimental group happened to have slightly higher capability beliefs at the beginning of the study.

In order to gain further insight into the relationship between PAB patterns and inquiry teaching practices, the researchers conducted interviews and used the Horizon observation protocol to observe seven participants in the experimental group. As in previous studies (Andersen et al., 2004; Haney et al., 2002;), the researchers found that, in general, there were consistent relationships between the elementary teachers' personal agency beliefs and their implementation of inquiry teaching methods. Two of the seven teachers were exceptions to this general pattern. Although both teachers reported a high level of confidence in their science teaching and were therefore classified as having a robust personal agency belief pattern, observations revealed substantial problems with their implementation of inquiry teaching methods.

Although this preliminary research on teachers' personal agency beliefs provides some insight on the factors that motivate teachers' to pursue science education reform, the limitations of these first studies suggest important questions for future research. Existing studies consider context an important determinant of teachers' decision-making and behavior, as evidenced by their investigation of teachers' context beliefs; however, researchers have yet to explore how personal agency belief patterns may cluster or vary according to school contexts. Given the complexity of the teaching policy environment and the impact of policy on science education reform, determining how personal agency beliefs patterns vary across and within comprehensive school reform models can inform the implementation of science initiatives. For example, in developing professional learning opportunities, district staff may approach schools where teachers' tend to have robust personal agency belief patterns much differently than schools where teachers are more likely to exhibit antagonistic personal agency beliefs.

CHAPTER 3: METHODOLOGY

Recall that the study was guided by the following research questions:

1. To what extent do science teaching practices vary across the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?
2. How is time for science allocated in schools implementing the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?
3. To what extent do teachers' personal agency beliefs vary across the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?

Study Design

This study represents the second phase of a research program employing an explanatory mixed methods design (Creswell & Plano Clark, 2007) in which the analysis of quantitative data is being followed by the subsequent collection and analysis of qualitative data. Creswell and Plano Clark (2007) describe two major variants of the explanatory mixed methods design – the follow-up explanations model and the participant selection model. The follow-up explanations model is well suited for situations where the researcher needs qualitative data to explain significant quantitative results, whereas the participant selection model is employed when a researcher uses quantitative data to identify participants for a qualitative follow-up study. As described below, the proposed study incorporates both the follow-up explanations and the participant selection variants of the explanatory mixed methods design.

Pilot Study

In the pilot study, 109 elementary teachers implementing six comprehensive school reform models within the participating district completed an online survey which included scales from two previously developed instruments: the Science Teaching Efficacy Beliefs Instrument (Riggs & Enochs, 1990) and the Context Beliefs about Teaching Science Survey (Lumpe, Haney, & Czerniak, 2000). These scales measured teachers' self-efficacy beliefs, their beliefs about which environmental factors would enable effective science teaching (e.g.: enable beliefs), and their beliefs about the likelihood that such environmental factors would occur at their schools (e.g.: likelihood beliefs).

The analysis of quantitative survey data identified results to be explored further in the dissertation. Both traditional and Rasch analyses indicated a significant difference in teachers' beliefs about their school context across reform models ($F = 6.2$, $p < .001$). In particular, teachers in schools with the Direct Instruction reform model scored significantly lower on the likelihood scale than teachers in schools with other reform models, suggesting that teachers implementing the Direct Instruction reform model tended to doubt that environmental factors that would enable effective science teaching would occur in their schools. Additionally, across reform models, teachers identified environmental factors related to time, such as planning time and extended class period length, as resources that were particularly important but unlikely to occur. Finally, the pilot study highlighted certain aspects of the organizational context and professional peer community, such as teacher involvement in decision-making and the support of administrators and other teachers, as factors that would enable science teaching but were not always likely to occur at the school level.

Participants

Three reform models were purposefully selected for this study: Core Knowledge, Direct Instruction, and International Baccalaureate. According to Miles and Huberman (1994), "by looking at a range of similar and contrasting cases, we can understand a single-case finding, grounding it by specifying *how* and *where* and, if possible, *why* it carries on as it does. We can strengthen the precision, the validity, and the stability of the findings" (p. 29). The selection of these cases according to a maximum variation strategy (Miles and Huberman, 1994) was guided primarily by the Rasch analyses of pilot study results, which produced a variable map suggesting that teachers in schools with the International Baccalaureate, Core Knowledge, and Direct Instruction models may possess high, moderate, and low likelihood beliefs, respectively. Additionally, reviewing literature on various reform models reveals that these three models represent a range of approaches to teaching and learning. Finally, each model is popular nation-wide and currently being implemented in multiple schools within the district.

Initially, teachers at three elementary schools implementing each reform model were recruited to participate in the study. To the extent possible, schools that 1) are currently implementing each reform model, and 2) have teacher and student demographics representative of the district were included. Teachers were recruited for focus group discussions by email and announcements made at school faculty meetings. Due to scheduling conflicts, only six of the original nine schools – two schools within each reform model – had enough teachers who were available to participate in focus group discussions. Following the focus group discussions, individual interviews were conducted with two additional teachers from each school. Interview participants were teachers who either expressed interest in participating in their school's focus group but could not attend at the scheduled time or teachers who were referred by colleagues at their school who did attend the focus group discussion. Demographic information for focus group and interview participants is presented in Tables 1 and 2.

Responses to open-ended response items were drawn from a sub-set of participants in the previous quantitative survey study. Prior to completing the quantitative measures, teachers from schools implementing a variety of reform models completed a series of open-ended questions. Only responses from participants within the three targeted reform models will be analyzed for the current study. Survey participants included a total of 55 elementary teachers - 17 teachers implementing the Core Knowledge reform model, 20 teachers implementing the Direct Instruction reform model, and 18 teachers implementing the International Baccalaureate reform model. Demographic information for survey participants is presented in Table 3.

Participants for the observation phase of the study were drawn from the pool of focus group participants. One teacher within each comprehensive school reform model was selected according to three criteria. First, the three teachers were selected among those focus group participants who are willing to participate in three, daylong observations and subsequent debriefing sessions. Second, the selected teachers had at least 2 years experience implementing their school's comprehensive school reform model. And, third, the teachers expressed their commitment to science education and to implementing the district's science education initiative. Beyond these criteria, to the extent possible, teachers were chosen who taught at the same grade level and had comparable teaching and educational backgrounds (i.e. Years teaching at current school, science courses taken in college). Table 1 denotes the three third grade teachers selected as observation participants.

Note that in reporting the findings of this study, letters and numbers are used to identify teachers and schools rather than pseudonyms. Each of the two schools participating in a focus group is referred to as either School A or School B. Teachers are referred to by their grade level, school, and/or reform model (i.e. a third grade teacher) and numbers (i.e. Teacher 1, Teacher 2) within exchanges among multiple teachers, as often occurs in focus group conversations. The reason for these conventions is three-fold. First, the focus and major unit of analysis for the study and the cases of interest are the three reform models, not specific teachers or schools. Second, although data for all teachers was coded and analyzed, the number of teachers and schools participating in the various aspects of the study (focus group, interview, and survey) and the amount of resulting data necessarily means that many individual teachers will not be directly quoted within the findings, making it unnecessary and impractical to assign pseudonyms to the over 100 teachers who participated in the study. Finally, given the number of teachers participating in the study, the use of pseudonyms would likely result in confusion for readers who would likely find it difficult to track individually named teachers throughout the study.

Setting

District Context

This study took place in a large urban school district in the southeastern United States. The district includes 57 elementary schools, 17 middle schools, 19 high schools, two single-gender academies (6-12th grade), and seven charter schools. The district served approximately 57,000 students during the academic year in which data were collected (2010-2011). The ethnic makeup of the district's student population is 86% percent African American, 8% Caucasian, 4% percent Hispanic, and less than one percent Multi-racial, Asian, or American Indian. Seventy-six percent of the district's students are eligible for free and reduced priced meals and eighty-seven percent of the district's schools are designated as Title I schools. Of the 2,084 elementary teachers working in the district during the 2009-2010 academic year, 71% identify as African American, 25% identify as Caucasian, 3% identify as Hispanic, 1% identify as Asian, and less than one percent identify as Multi-racial, American Indian or Pacific Islander. Eighty-five percent of the district's K-5 teachers are female.

Comprehensive School Reform. A school reform agenda initiated by the district's Superintendent during the 1999-2000 academic year requires all Title 1 schools in the district to implement a research-based comprehensive school reform model. Reform model implementation in the district has been supported in large part through the Comprehensive School Reform Demonstration Program passed by Congress in 1997 and ultimately expanded with the passage of NCLB in 2001 (Cross, 2004). Under this program, grants for reform model implementation were made to state education agencies and subsequently administered as competitive sub-grants to local education agencies and schools. Between 1999 and 2005, individual schools in the participating district applied for and received these sub-grants to support the adoption of comprehensive school reform models.

Although federal funding for the Comprehensive School Reform Program expired in 2005, all Title 1 schools in the district continue to implement comprehensive school reform models. The variety of reform models adopted across the district has resulted in a range of approaches to instruction, assessment, classroom management, professional development, parental involvement, and school management.

The Math-Science Initiative. The participating district has made a public commitment to improving student achievement in science. In 2007 the district received a grant from a major corporation for 22 million dollars to support a five-year Math-Science Initiative. According to the district's 2006-07 Annual Report, this 5-year initiative represents the "largest mathematics and science professional development and curriculum program in the nation" and aims to prepare "educators to use project-based, hands-on techniques in order to help prepare students for technical careers that are in demand around the world."

Having focused primarily on improving teaching and learning in mathematics during the first three years of the Math-Science Initiative, the district committed to pay increased attention to science during the 2009-2010 and 2010-2011 school years. This renewed commitment to science education includes district-wide professional development and an increased investment in science curriculum and resources. At the beginning of the 2009-2010 school year, all elementary teachers in the district took part in a daylong "Focused Professional Learning" conference. At this conference, teachers participated in a variety of sessions related to the district's efforts to improve science education. All teachers attended grade level content overview sessions in which they reviewed State science standards, explored the district's revised curriculum map and scope and sequence documents, and observed teacher leaders modeling one of the hands-on "Essential Labs" that will now be required in all elementary classrooms.

Additional sessions focused on district recommendations regarding lab safety and the district-wide implementation of science notebooks. Additionally, third through fifth grade teachers were introduced to an E-Learning program that makes use of online tools sponsored by the National Science Teachers Association.

Data Sources

Data were drawn from a variety of qualitative data sources including responses to open-ended survey questions, focus group discussions, interviews, and documents. Each of the proposed data sources is described below and Table 4 presents data sources by research question.

Open-Ended Response Items

Teachers responded to the following open-ended response items regarding their science teaching experiences and their school's approach to science education:

1. Think about your school's approach to science education. What advice would you give a teacher who is preparing to teach science at your school for the first time?
2. Think about science in your classroom. If someone observed a science lesson in your classroom, what would they most likely see and hear? Please share specific examples.
3. Think about student learning in science. What has your teaching experience taught you about how students learn science concepts? How do you define student success in science?
4. Please share anything else that would help me understand your experience teaching science or science education at your school.

The number, content, and wording of these questions was determined through pilot testing. Teachers were instructed to type their responses into a text box field on the online survey. In order to ensure that teachers' responses were not influenced by material in the other surveys, teachers completed the open-ended items before completing the other surveys.

Focus Groups

Creswell (1998) suggests conducting focus group interviews when individuals may be reluctant to provide information in the context of a one-on-one interview. Given the emphasis that is often placed on implementing school reform initiatives with "fidelity", teachers may be hesitant to reveal ways in which their school has modified either their reform model or the district science initiative. Additionally, given the collaborative nature of leadership for science teaching in urban schools (Spillane, 2001), focus group interviews may be conducive to illuminating the ways in which networks of teachers interact with and understand their school context.

Ninety-minute focus groups were conducted at each of the six selected schools. As suggested by Morgan (1997), between 6-10 participants were recruited to participate in each focus group and over-sampling was employed to increase the likelihood of adequate attendance. Due to scheduling conflicts, between 5 and 7 participants were able to attend the focus group discussions. Teachers who expressed interest in participating in a focus group but were not able to attend the focus group session were contacted to participate in individual interviews. The focus groups were conducted in a quiet space at each school (e.g. library, conference room, classroom) at a date and time that was convenient for the greatest number of teachers interested in participating.

Focus group sessions were semi-structured, following the “funnel” approach suggested by (Morgan, 1997). This approach recommends beginning with a more open, free discussion before transitioning to a more structured discussion of specific topics. A focus group protocol (Appendix B) was revised according to feedback from a pilot focus group with science educators (n=4) and an hour-long peer-review session. Revisions included minor changes in the sequencing and wording of several questions with the goal of improving the organization and clarity of the protocol. Colleagues’ specific suggestions regarding logistics, transcription, and strategies for focus group moderation were recorded in a researchers journal for future reference. After the first focus group, further revisions to the protocol were made. Specifically, additional follow-up questions regarding teachers’ self-efficacy were included, including several adapted from the Science Teaching Efficacy Beliefs Instrument.

All focus groups were recorded with a digital recorder. As suggested by Morgan et. al. (Miles & Huberman, 1994) Contact Summary Forms (Appendix C) were completed immediately after each session in order to capture my impressions and reflections about each focus group discussion. Whenever possible, recordings were transcribed before conducting the next focus group. Printed transcripts and survey data were stored in a locked filing cabinet. Digital files, including soft copies of transcripts, focus group recordings, and all survey data were stored securely on a password-protected personal computer and network user space. Prior to participating in focus group discussions, all participants completed an informed consent form (Appendix D) previously approved by the Emory University Institutional Review Board and the Office of Research and Accountability at the participating school district.

Interviews

Semi-structured interviews with twelve teachers (two teachers from each participating school) were conducted following focus group sessions. Individual interviews were intended to supplement focus group data and gain additional insight into each school's approach to science education as well as individual teachers' science teaching practices and personal agency beliefs related to science. The protocol used for the focus group sessions was adapted to create the interview protocol (Appendix E). Each interview lasted approximately one hour. Following the interview, I contacted teachers by email or telephone to thank them for participating, ask any follow-up questions that occurred to me after the interview, and invite teachers to share any additional comments related to the study.

Classroom Observations

Merriam (2009) contends that "observation, when combined with interviewing and document analysis, allows for a holistic interpretation of the phenomena being investigated" (p. 136). To this end, three days were spent observing one teacher within each of the three reform models. Given limitations on time and access, the purpose of observations in this study is not to create an ethnography, but rather as a method of triangulation and to serve as the basis for generating thick description of science education in the context of the three reform models being examined.

In order to gain insight into how science teaching and learning is (or is not) integrated within the school day and with the requirements of each reform model, observations took place within the same school week and over the course of the teacher's school day, beginning when the teacher arrives at the school site and ending when the teacher leaves the school site. Thus, the observation included both formal instructional time as well as time spent meeting with or interacting informally with students and colleagues. I used the Reformed Teaching Observation Protocol (RTOP) (Sawada, Piburn, Falconer, Turley, Benford, and Bloom, 2000) to guide my observations of any science lessons that took place during the three-day observation period. The RTOP is designed to assess the degree to which mathematics or science instruction can be considered “reformed”, based on criteria derived from recommendations within various reform documents (e.g. AAAS Benchmarks for Science Literacy, Project 2061, National Science Education Standards). The protocol includes 25 items that are rated from 0 (not descriptive) to 5 (very descriptive). The items reflect 5 subscales related to the following dimensions: Lesson Design/Implementation, Content: Propositional Pedagogic Knowledge, Content: Procedural Pedagogic Knowledge, Classroom Culture: Communicative Interactions, and Classroom Culture: Student-Teacher Relationship. Sample items for each subscale of the RTOP instrument are provided in Appendix F. Additionally, detailed field notes pertaining to each of the three research questions were taken throughout each school day.

Depending on the activities being observed and the preferences of the participants, I assumed either a passive participant or peripheral membership role as defined by Adler and Adler (1994). As a passive participant observer my presence was known to the teachers and students; however, I did not interact directly with either the teacher or students. The peripheral membership role is characterized by interacting frequently and intensively enough with participants to gain firsthand information without becoming fully involved in the activities being observed. For example, although formal interviews were not conducted with observation participants, when possible, I engaged teachers in informal discussion about their science teaching practices and their school's approach to science education.

Documents

A variety of documents were analyzed to gain further insight into the compatibility of the district science education initiative and comprehensive school reform. School, district, and comprehensive school reform documents were collected through a variety of sources including from teachers, from school and district staff, by attending district professional development programs, and by accessing publicly available information on the internet. Documents include school schedules, school and district mission statements, science lesson plans, information from each comprehensive school reform model's website, and press releases and instructional materials related to comprehensive school reform and/or the science initiative (e.g. scope and sequence, information provided at district professional development sessions).

Teacher Questionnaire

As part of the pilot study, teachers completed a brief questionnaire in which they provided information about their teaching background as well as estimates of time spent on science education in their classroom. To address the second research question regarding time allocated to science education, the estimates provided by teachers in Direct Instruction, Core Knowledge, and International Baccalaureate schools supplemented data gathered in focus groups, interviews, documents, and observations.

Data Analysis

Teachers' responses to open-ended survey items, focus group and interview transcripts, observation field notes, and documents were subjected to sequential analysis (Miles & Huberman, 2004) beginning with two levels of coding. First, using the NVivo software program, I applied a provisional "start list" of codes drawn from the Knapp and Plecki (2001) and Ford (1992) frameworks. This coding scheme was refined throughout the first round of iterative coding, with codes being added, revised, combined, or eliminated as necessary. For the second round of coding, pattern codes were applied in order to identify emergent themes. I drafted short memos to capture any explanations, relationships, and methodological considerations that occurred to me during the coding process.

The next stage of analysis involved constructing a partially ordered meta-matrix (Miles & Huberman, 1994) to display evidence for emergent themes and propositions related to each of the research questions. Such meta-matrices serve as useful "master charts assembling descriptive data from each of several cases in a standard format" (Miles and Huberman, 1994, p. 178). These charts served as a reference when synthesizing and drafting the results of the study.

Validity and Reliability

Creswell and Plano Clark (2007) define validity in mixed methods research as "the ability of the researcher to draw meaningful and accurate conclusions from all of the data in the study (p. 146)". This definition implies a need to address potential validity issues inherent in each of the data sources employed in this study as well as any potential threats to validity that arise from combining these sources.

Internal Validity

Strategies for strengthening the internal validity of this study include the triangulation of data sources and peer review. Stake (1995) defines triangulation as a strategy that "looks to see if the case remains the same at other times, in other spaces, or as persons interact differently" (p. 112). In the proposed study, triangulation was accomplished by utilizing multiple data collection methods at multiple research sites. Participants' written responses to open-ended questions, interactions and comments within the context of focus group interviews, individual interviews, and observed practices were considered when analyzing and interpreting the data. Face validity was be established by gathering feedback from peer reviewers. Validity was further strengthened through the use of member checks. Specifically, at the conclusion of each focus group or interview, teachers were asked to confirm the major points that emerged during the discussion. Additionally, transcripts were shared with focus group and interview participants who were encouraged to provide clarification or revisions to any of the comments they made during the focus group or interview session. Only one teacher provided a clarifying comment in response to their focus group transcript – all other teachers responded that their transcript accurately captured their comments.

Despite these efforts to strengthen validity, one limitation of the study is its dependence on self-report measures. As has been noted in previous studies, teachers' responses on surveys and in focus group interviews may not reflect their actual classroom practice. Additionally, because the internal, largely implicit nature of beliefs makes them particularly difficult to articulate, it is possible that teachers' responses to the open-ended response items may not reflect their actual beliefs about science education and school reform. Although the study includes classroom observations in order to gain insight into teachers' practices and the extent to which they mirror teachers' survey and focus group responses, the fact that only one teacher within each reform model was observed necessarily limits the validity of the observation data.

Researcher Perspective. The explication of researcher perspective and positionality represents another method for strengthening internal validity (Denzin & Lincoln, 2005). My interests, identity, and background are inevitably and inextricably linked to my work as I carried out the study. I anticipate that three aspects of my perspective, in particular, had the potential to influence my approach to data collection and analysis in this study: my identity, my academic background and interests, and my relationship to and prior experiences within the research setting.

Although time constraints prevented me from becoming familiar with each of the schools involved in the study or developing personal relationships with each of my participants, by inviting narrative responses I hoped to provide a space for all teachers to make their voices heard in ways that may not be possible within the power structures in which they work (Mertens, 2007). As suggested by Miles and Huberman (1994), I honestly informed participants about my intentions, the goals of the study, and my methods for data collection and analysis. Consistent with the transformative paradigm (Mertens, 2007), I made explicit the connection between my research and my commitment to expanding opportunity for quality science education in urban elementary schools. By adopting the cyclical, rather than a linear, approach to research, I hope to maintain contact and continue my engagement with school communities beyond the period of data collection for this study.

Prior to my work in educational studies, I accumulated over five years of experience conducting basic research in cognitive development. Because much of this work focused on investigating the cognitive processes underlying science learning, I am in a privileged position when it comes to understanding many of the recommendations offered in the science education reform literature. Just as this content knowledge enhanced my work as an educator, it lends insight into my assessments of science reform implementation. However, given that most elementary teachers are not cognitive scientists, it will be important for me to avoid imposing unrealistic expectations or assumptions regarding my participants' knowledge about and interest in the science of science learning.

Finally, and perhaps most significantly, having spent two years as a first grade teacher in one of the participating schools, I come to the study with my own perceptions of the effects of policy on science education and reform. I have recent first hand experience with many of the policies being implemented within the district, including No Child Left Behind, Comprehensive School Reform, and the State's accountability and assessment programs. Given my previous employment by the district, I encountered several former colleagues or supervisors in the course of completing this study. Although my familiarity with the local context facilitated access, I recognize that this familiarity also carries the potential for researcher bias. Recording critical reflections in a researcher journal and memos as well as the processes of peer review and triangulation aided in my effort to conduct careful, responsible data collection and analysis.

External Validity

External validity refers to the extent to which the findings of a study can be generalized to other contexts (Merriam, 2002; Miles & Huberman, 1994). Though generalizability may not be a primary concern for case study research (Merriam, 2002), employing strategies to maximize external validity only strengthen the practical significance of the study. The threats to external validity include the study's focus on one urban district and its focus on three comprehensive school reform models. The study is being conducted within the boundaries of a single state and school district. Because policy conditions vary at the state, district, and school levels, the results of the study may not be generalizable to school contexts with different standards, comprehensive school reform models, or science reform initiatives.

Miles & Huberman (1994) suggest several guidelines for assessing the external validity of qualitative research that apply to this study. Thick description including quotations was included to help readers determine whether the results of this study could apply in other settings. The number of teachers involved in focus groups was as large as possible and multiple schools within each reform model were invited to participate. By maximizing the number of teachers and schools participating in the study, I believe I am able to offer insights that are likely to be useful for other schools in this district, for schools in similar urban districts, and other schools implementing the reform models under investigation. Finally, describing the study's data sources, procedures, and analyses in detail means that other researchers could replicate the study in other contexts.

Reliability

In qualitative research, reliability depends more on establishing and following systematic data collection and analysis procedures than on replicability, as in quantitative research (Maxwell, 2004). Merriam (1998) further defines reliability in qualitative research as the dependability or consistency between the data and the findings for the study. Intra-rater reliability was addressed by repeated coding of transcripts at various time points. Peer review, maintaining an audit trail, and keeping a researcher's journal were other methods used to increase reliability. Peer review was used to facilitate consistent application of my coding schemes and to control for coder drift. An "audit trail" (Merriam, 1998, p. 207) was maintained by developing systems to organize and label all data and analyses and by tracking any changes made to documents involved in the research process. In conjunction with the "audit trail", I used a researcher's journal to record decisions and changes that were made as data were collected and analyzed.

CHAPTER 4: RESULTS

The purpose of this study was to examine elementary science education within the context of three comprehensive school reform models. Specifically, data were collected and analyzed in order to explore the science teaching practices, allocation of time for science, and personal agency beliefs of teachers implementing three comprehensive school reform models (Direct Instruction, Core Knowledge, and International Baccalaureate).

Guided by Ford's (1992) framework detailing the construct of personal agency beliefs and Knapp and Plecki's (2001) framework articulating the forces and conditions that influence science teaching and learning in urban contexts, I analyzed a variety of qualitative data sources (focus groups, individual interviews, open-ended survey responses, and classroom observations) to gain insight into science education within the context of each reform model. For each research questions, I present findings pertaining to each of the three reform models followed by an analysis of relevant aspects of science teaching and learning across reform models.

Research Question 1: Science Teaching Practices

The following section describes the observed and reported teaching practices in Direct Instruction, Core Knowledge, and International Baccalaureate Schools. Teachers' observed science teaching practices are based on three-days of observation in one school implementing each reform model. For these observations, detailed field notes were taken the entire school day and any science lessons taught were assessed using the Reformed Teaching Observation Protocol (RTOP) (Appendix F). Recall that the RTOP was chosen as an observation instrument because it is designed to assess the degree to which math and science teaching is reformed and thus, its scales clearly reflect the goals of recent science education reform initiatives, including the district's Math-Science Initiative. The items on the RTOP were adapted to create a list of start codes used to analyze teachers reported science teaching practices shared in open-ended survey items, focus groups, and interviews. Additional codes were added to reflect reported teaching practices not included in the RTOP instrument.

Teaching practices in Direct Instruction schools

Observed Science Teaching Practices. During the three-day observation period in one Direct Instruction classroom, only one 22-minute-long science lesson was observed. This lesson began with a 3-minute-long classroom discussion in which the teacher asked students to recall and record the definition of the term "habitat". Following this discussion, the teacher directed students to independently read an excerpt from their textbook and complete a worksheet in which students matched various animals to their habitats. The lesson concluded with the teacher providing a second worksheet as a homework assignment. This assignment asked students to again define the term habitat and choose an animal and draw a picture of them in their native habitat. RTOP scores for this lesson, presented in Table 5, reflect relatively low degree of reformed science teaching in four of the five sub-scale categories. Salient observations related to each sub-scale are described below.

According to the RTOP, the degree to which instruction takes students' prior knowledge into consideration is one key indicator of reformed science teaching. Although the teacher asked two student volunteers to recall the definition of "habitat" for the class, this short discussion did not provide the majority of the class with an opportunity to express their prior knowledge or preconceptions pertaining to the concept. At one point the teacher does prompt a student with a question about the reading to ask one of their classmates saying, “Hmm. Good question, why don’t you see if one of your teammates knows the answer” (Classroom Observation, 5/3/10), an indication that the teacher values students’ knowledge and aims to engage students’ as members of a learning community. However, rather than being a key feature of the lesson, this instance was relatively minor and involved very few students.

Although the lesson involved fundamental concepts included in the State’s 3rd Grade Science curriculum and the teacher demonstrated relatively strong content knowledge, the degree to which the lesson achieved the RTOP’s stated goal of promoting “strongly coherent conceptual understanding” is questionable. Students existing conceptions of the habitat concept were not explored and connections to related concepts or other science content were not emphasized. Instead, the primary goal of the lesson was for students to merely define and identify isolated examples of the “habitat” concept. At several points in the lesson, the teacher overlooked student statements and questions that could indicate possible misconceptions. For example, in completing her assignment, one student asks “what if it snows, then it’s a different habitat?”, suggesting the possibility of confusion between the concepts of climate and habitat. Instead of engaging the student in further discussion to elucidate her understanding, the teacher merely states, “Yes, some habitats have snow and some do not” (Classroom Observation, 5/3/11).

Opportunities for students to exhibit or practice procedural knowledge were also scarce within this lesson. The handouts, a drawing on the board, and textbook illustrated the concept in various modes; however, with the exception of the drawing assigned for homework, students were not actively involved in creating these representations. Students were not asked to make predictions or to suggest methods for testing hypotheses and students did not seem to find the lesson particularly thought-provoking or rigorous. Although the lesson itself did not prompt students to reflect on their learning, a few students did spontaneously reflect on how they already knew the concept prior to the lesson. For example, when asked at the beginning of the lesson to define the word "habitat", one student raises his hand and states "that's where you live…not just you, but any living thing..that's where they live. I knew that in 1st grade" (Classroom Observation 5/3/11).

Because the lesson was almost entirely teacher-directed, students had few opportunities to share their ideas, either with their peers or their teacher. Students spent the majority of the lesson reading and completing worksheets independently, with no interaction with each other or the teacher. There was almost no student talk and the student talk that did occur was between the teacher and the students. Similarly, the teacher asked only one question the entire class period ("What is a habitat"?) and therefore failed in asking questions that trigger divergent modes of thinking. Although the overall climate in the classroom was respectful, students who attempted discussion related to the content during the independent work portion of the lesson were reprimanded. For example, after completing his textbook reading, one student attempts to engage his peer in conversation stating "man, I want a houseboat habitat, out with the sharks". Before his friend can respond, the teacher demands silence, telling the boy "that's enough" (Classroom Observation, 5/3/11).

Reported Science Teaching Practices. Teachers' reported science teaching practices were gleaned from focus group discussions, individual interviews, and responses to open-ended survey questions. Table 6 presents the frequency with which teachers' comments were coded according to each of the RTOP indicators along with additional codes that emerged from the analysis of teachers reported teaching practices. Asked to describe a typical science lesson in their classroom, 54% of teachers from D.I. schools noted that their students engage in "inquiry" and 44% stated that their students participate in "hands-on" activities; however, as described below, when asked to describe lessons in more detail, the majority of teachers described a more traditional approach that does not generally align with the type of reformed science teaching implied by the RTOP instrument and the district's science initiative.

Over one third of the DI teachers in the study (38%) explicitly mentioned teacher presentation of science content and over half (54%) reported students' textbook reading and exercises as science teaching practices typical in their classrooms. While teacher presentation and the use of textbooks may certainly occur in even the most "reformed" science classrooms, many teachers descriptions of their science teaching practices suggest that these activities often took precedence over student inquiry. For instance, several teachers recounted a lesson sequence in which student investigations serve as an optional supplement to teachers' formal presentation of science content. In these examples, teachers seemed to see engaging in experiments or other "hands-on" activities as a way to review or reinforce science content learned through more traditional means rather than as a means for building conceptual understanding itself. For instance, one survey respondent outlines a typical science lesson as follows:

> During the introductory phases, there would be the introduction of new vocabulary. During the modeling stage, the explanation of the science content and expectations would be made as clear as possible. I would explain the ideas in several ways and give all students the opportunity to learn the content. During the practice stage, an environment of seriousness and respect will exist permitting the free flow of ideas and acceptance of mistakes. During the conclusion, discussions of results and the examination and analysis of mistakes would occur.

Although the lesson described here includes elements of inquiry-oriented science teaching, namely the "free flow of ideas and acceptance of mistakes" and student engagement in some sort of investigation, within this sequence it is clear that student investigation is permitted only after science content is presented and modeled by the teacher. Indeed, in stating that she would explain the content in different ways so that students would "have the opportunity to learn", the teacher equates her presentation of the material, rather than student inquiry, as the means by which students learn science content. Similarly, asked to describe what someone would observe if they visited her classroom during a science lesson, one focus group participant explains that inquiry would supplement a more traditional science lesson stating that "they would see the lesson start off with a review of the previous lesson, reading and discussing from the text, and then if we have time, some sort of science experiment or demo" (Focus Group, 3/9/11).

That the science lessons described by Direct Instruction teachers tended to prioritize the formal presentation of content over student inquiry seemed to reflect a broader reluctance to embrace a more student-centered approach to science instruction. The relative frequency of student inquiry versus more teacher-centered science instruction is apparent in one survey participants' description of her approach to science teaching: "vocabulary work to build background knowledge, textbook work to help with reading skills of expository texts, and a monthly lab to build inquiry skills." Not only does this teacher seem to believe that a single monthly lab experience is sufficient, it is interesting that the stated purpose of the lab is to build inquiry skills rather than develop conceptual understanding of science content. Indeed, at both Direct Instruction schools, focus group participants expressed conflicted views regarding the role of student inquiry. As evident in the following exchange, teachers reported that they felt that they should provide opportunities for exploration while at the same time contending that student-centered inquiry didn't always "work" in their classrooms (3/31/11):

> Teacher 1: Well, I know it should be more about experiments, like if we do the Essential Labs, but I don't really just let them go like that…
>
> Teacher 2: Yeah, I mean if you let kids just do their thing, explore and take it where they want it to go, you won't get anywhere
>
> Teacher 1: I mean, even when its got more of a structure to it, like in the labs you kind of guide them to ask certain questions and give them all the materials and they are supposed to find a way to test their question, it sounds good but I just don't see it happening that way
>
> Teacher 3: Right, its good in theory, but even if we had time, it seems to make more sense to make sure they are solid on the vocab and the ideas and then use

> the labs as enrichment to reinforce what they've just learned… to see it for themselves.

The statements that students should engage in "vocabulary work to build background knowledge" and that they should be "solid on the vocab" above highlight the persistent focus on teaching science vocabulary among many Direct Instruction teachers. Indeed, the importance of teaching science vocabulary was highlighted by 6 out of 13 focus group participants, by 14 of 22 survey respondents, and by 3 out of 4 interview participants. One interview respondent equates the mastery of science vocabulary with success in science, stating that "as a primary teacher, I define student success in science when they are able to use science vocabulary in their oral communication" (4/6/11). Similarly, one survey participant attests that "students learn science concepts by studying vocabulary. Science is all about the vocab and if you master that you will do well in science. Student success in science is to first find an interest in science and research scientific terms and learn them." For these teachers, science learning seems to be more a matter of mastering the language of science through the memorization of definitions than developing the ability to reason scientifically and develop deep conceptual understanding.

Although this more traditional mode of science teaching, with an emphasis on vocabulary acquisition and teacher-directed delivery of science content, was most common among Direct Instruction teachers, two teachers stand out as notable exceptions. One survey respondent, a 1st grade teacher who had been implementing the Direct Instruction model for 4 years, provides the following description of a science lesson in her classroom:

> During science lessons, students are usually engaged in inquiry-based investigations. Students can be seen talking, moving purposely around the room, writing in science journals, using technology and coming up with ideas for further investigation. Last week, our science lessons focused on shadows. We began by discussing pictures of shadows made in everyday life. Once students began thinking more deeply about how shadows are made and changed, we began an investigation of one particular picture. Using flashlights and a marker, students experimented with the placement of the light source. As they discovered more about shadows, we went back to discuss the shadow in the picture. Students ended up with lots more questions about shadows and started thinking about ways to do another investigation.

The connections to students' everyday lives, the elevating of student questions and "science talk", and the willingness to empower students to pursue answers to their science questions clearly set this lesson apart from examples provided by the majority of Direct Instruction teachers. This teachers' clear investment in inquiry-based teaching and the tension between her preferred approach and the demands of the Direct Instruction reform model are evident in her description of how students best learn science:

> I think students learn best when they get to express themselves, explore what they already know, and add to that knowledge by experiencing science concepts directly. I really do like to give my students the freedom to talk about their world and the science they do know in their words. I end up learning a lot about how they think that way. Unfortunately, test scores and vocabulary and scripted

programs (DI) tend to be more emphasized at my school - so I have to make sure we are meeting all those objectives and goals if I want to be left alone to teach some science at all.

One interview participant provides a second counter-example to the more traditional teaching reported by many direct instruction teachers. This 3rd grade teacher, a 10-year veteran who had been teaching at her school for 5 years, describes how her students' questions are central to her instruction (4/6/11):

> If you came to my class, you would probably observe students asking all sorts of interesting questions. That's really what science is about, how the kids understand their world and how it relates to science. Of course I teach the standards, but that's just a guide - I always start with the students' and their questions and I'm not afraid to get a little off track, to take a lesson in another direction if students are really excited and curious about investigating something.

Asked if she could provide an example of what this might look like in her classroom, she went on to describe a lesson on erosion. In this lesson, she had planned to have students simulate erosion by blowing through straws to change the shape of piles of sand on their desks. She explained how the lesson took a turn according to students' ideas (4/6/11):

This was going fine, the kids were really getting it and making connections and one of my boys asked 'what about water - would it look different if we showed the erosion with water?' So, I basically threw out the rest of my plan and the kids came up with a way to look into his question…When I first started teaching, I would have never done that… I would have just answered the question 'cuz I'd be afraid of the mess and worried about not getting through my lesson, but I've learned that when the kids take charge is really when it gets good…it might get messy, but there's learning going on.

In elaborating on her approach to science teaching, this teacher further explains the "messiness" of science learning and draws a direct comparison to Direct Instruction:

It might look a bit unfocused to an outsider, but "real" science learning isn't as neat we make it out to be. I hope someone would recognize that my students are taking risks and that they are sharing their ideas, not just talking. Someone who hasn't spent time in my classroom might also think that it's a big mess during science time, because we have all sorts of "stuff" out, especially compared to when we do DI.

Teachers' reports shed light on the science teaching practices in Direct Instruction schools. Although teachers commonly used the terms "inquiry," "experiment," and "hands-on learning," the vast majority of Direct Instruction teachers who participated in this study actually described a more traditional mode of science teaching than is called for by the district's science initiative. Although teachers did not explicitly connect their more traditional science teaching practices to their implementation of the Direct Instruction reform model, it is noteworthy that the two exceptional teachers who did provide clear evidence of inquiry-based science teaching both highlighted the tension and inconsistency between their preferred science teaching practices and Direct Instruction.

Teaching Practices in Core Knowledge Schools

Two science lessons were observed during the three day observation period in one Core Knowledge school. Both lessons were part of a six-lesson unit on Rocks and Minerals. The first lesson focused on the characteristics of metamorphic rocks. In this lesson, students were introduced to various types of metamorphic rocks. The lesson began with the teacher asking students if they could name the three types of rocks. After naming the three types of rocks the students would be studying (metamorphic, igneous, sedimentary) and noting that the current lesson would focus on metamorphic rocks, the teacher asked students if they knew what the word morph meant. After calling on two students to share, the teacher presented information on metamorphic rock while students took notes. The teacher then directed students to complete an activity in which they colored pieces of paper to represent different types of metamorphic rock (limestone, shale, sandstone) and then changed the appearance of each colored square to illustrate changes in the various rocks. For example, students were directed to crinkle and then rub a crayon over the creases in the limestone square to simulate changing limestone into marble. In the second lesson, students focused on igneous rock. The lesson began by having students review the three types of rock. The teacher then wrote several facts about igneous rock on the board while students took notes. The teacher then performed a demonstration in which she showed students a container with marbles settled in the bottom and then shook the container to symbolize the movement of molecules that occurs when the temperature of magma within the earth increases. The teacher then described various types of igneous rock (obsidian, granite, pumice, and basalt) and students recorded rock characteristics on a worksheet. The students were then instructed to write a story about how a type of igneous rock is formed.

Taken together, these two lessons include elements of reformed science teaching but, according to the criteria laid out in the RTOP, ultimately fall short in providing students with a science learning experience that is likely to result in coherent conceptual understanding. At the beginning of each lesson, the teacher briefly quizzes students on the names of different types of rock; however, students' prior knowledge regarding the primary objective of the lesson ("Students will describe the process of rock formation") was unexplored. After the first lesson, when I asked the teacher whether she had considered asking students to describe how rocks were formed prior to presenting the information in a lecture format, she stated that she thought that sort of in depth questioning would be too time consuming and that "students haven't learned it yet, so who knows what they'll say" (Classroom Observation, 5/9/11).

This attitude suggests a tendency to disregard the importance of students' prior knowledge and exploration in favor of a more teacher driven mode of science instruction focused on the acquisition of scientific facts. Although the objective for the lessons clearly emphasized the process of rock formation, the teacher seemed most concerned that students be able to name the types of igneous and metamorphic rock and recall basic facts about each type of rock. Through the coloring activity, students learned that certain changes can cause changes in the appearance and classification of metamorphic rock (i.e. limestone changing into marble); however, the teacher was generally unable or unwilling to explore students' questions about *how* and *why* these changes occur. For instance, while coloring her square representing marble one student asked where the lines in the rock come from and why they are darker than the rest of the rock. Instead of engaging the students' in discussion about this process that was central to the lesson objective, the teacher simply states “that’s a good question. You’ll learn more about that if you study rocks in college.” Similarly, when the demonstration included in the second day’s lesson provoked questions among students about the formation of igneous rock, the teacher devoted very little time to addressing students’ questions in order to reserve instructional time for her lecture and its accompanying worksheet. Although the assignment to write a story about how a type of rock was formed could potentially serve as a valuable learning experience and opportunity for students to share their developing understandings of rock formation, little class time was devoted to this activity. Indeed, when I asked the teacher about the rock story assignment after the lesson, she stated that she considered the stories an “enrichment activity” and noted that students weren’t likely to have additional time to finish or share their stories with the class. The teacher also noted that students’ worksheets and notes, rather than their stories, would serve as the basis for her assessment of student learning. Asked if she thought students’ would do well on the unit test that would cover the various rock types, she responded that her students’ usually do very well on this unit and that they generally have no trouble naming and describing the characteristics of different types of rock. When I asked whether she believed her students could describe the process of rock formation, she stated that “some students may have picked up ideas on that, but we’re really focused on making sure they know the most important basics” (Classroom Observation 5/9/11).

Reported Science Teaching Practices. As with the Direct Instruction teachers, the reported science teaching practices of Core Knowledge teachers were gleaned from focus group discussions, individual interviews, and responses to open-ended survey questions. Table 6 presents the frequency with which teachers’ comments were coded according to each of the RTOP indicators along with additional codes that emerged from the analysis of teachers reported teaching practices. Similar to Direct Instruction teachers, when asked to describe a typical science lesson in their classroom, teachers from Core Knowledge schools often noted that their students engage in “inquiry”, “experiments”, or “hands-on” activities; however, when asked to describe lessons in more detail, some of these teachers described a more traditional approach. In particular, consistent with the classroom observation findings, Core Knowledge teachers frequently emphasized the acquisition of scientific facts and vocabulary as an important, and sometimes primary, goal of their science teaching. Additionally, teachers highlighted the integration of science with other subject areas as an important element of their science teaching.

Although the Core Knowledge model outlines *what* science content students at various grade levels should learn, the model does not provide standardized instructional materials or prescribe *how* science (or any other subject area) should be taught. Collections of lesson plans have been developed by various groups implementing Core Knowledge and these materials are made available to teachers implementing the model; however, individual schools and teachers are permitted to incorporate whatever strategies and resources they wish into their science teaching. Consequently, teachers in Core Knowledge schools report using a wide variety of approaches to science teaching and learning.

As indicated in Table 6, 69 percent of teachers in Core Knowledge schools used term “inquiry” and 57 percent used the term “hands-on” when describing their approach to science instruction. However, how these terms translated into classroom practice varied widely across the sample, with some teachers describing lessons that clearly prioritized student inquiry and others relegating inquiry to a “bonus” enrichment activity meant to reinforce content learned in a more traditional fashion. This variation occurred both across and within Core Knowledge schools, as evidenced by the following exchange that occurred within one school focus group (2/23/11):

> Teacher 1: One thing that’s good here is that, well it’s that each teacher is free to teach their way.
>
> Teacher 2: Sometimes a grade will do lesson planning together, more jointly, but even then you can figure to do it the way you want
>
> Teacher 1: So we all have different styles, it’s not that some are better or worse, its just different… so I do a lot of experiments and the like with my students - most every day we are lab or sometimes they have a question that goes with an’ I go ahead and set a whole day for us to design a study on that.
>
> Teacher 3: Right - and all that’s great - sometimes we’ll get to a lab, but it just looks different in my room. It’s 5th grade - I want them getting ready for middle school and taking responsibility, so there’s a lot more reading and note taking. Learning to take notes is sort of a big deal for them to learn. It probably looks a lot more serious.

Although teachers repeatedly used the term “inquiry” to describe effective science teaching, it should be noted that it was not at all clear teachers were using the term “inquiry” as intended by science education reform initiatives, such as the one implemented in their district. For instance, one hallmark of inquiry oriented science teaching is that student exploration precedes formal instruction. In this way, students have the opportunity to activate their prior conceptual understanding prior to receiving additional content that may advance their understanding of the concept further. Each of the Essential Labs required by the district's science initiative follow this pattern of student exploration preceding formal instruction; however, in speaking of their implementation of the Essential Labs, several Core Knowledge teachers discuss how they intentionally reversed the order of the lesson activities so that the inquiry became a supplement to the formal instruction (Focus Group, 3/10/11):

> Teacher 1: I thought the lab activities were good, but some didn't really make sense.
>
> JG: What do you mean "make sense"?
>
> Teacher 1: Well, the order was off. Like, well they'd have kids experimenting or doing some hands-on thing that I thought was pretty good, but they'd do this before we taught the topic...so it got confusing.
>
> Teacher 2: Right. I guess the idea is they do the activity and then you explain it, but my kids do better if you explain first.
>
> JG: Can you give me an example?
>
> Teacher 3: (Pause) Well, ok, in my grade one of the standards is identifying different groups of animals. So you could give kids a bunch of examples or figures or pictures, just a bunch of 'em, of different animals and have them try to see what's different about them and how they go together or not, like mammals, fish, reptiles etcetera, etcetera.
>
> Teacher 1: or you can make sure they know the types and then use the hands-on part to build on it.

Although they may have adapted labs to fit their individual teaching styles, the vast majority (74%) of Core Knowledge teachers did explicitly mentioned implementing the Essential Labs mandated by the district's Math/Science Initiative. All of the teachers participating in focus groups and interviews and ten of nineteen survey respondents reported that, to varying degrees, they incorporated the Essential Labs into their science instruction. Several teachers cited time constraints and noted that the labs were short enough that they could fit them into their limited instructional time for science without sacrificing time to prepare students for standardized tests in mathematics, reading, and English/Language Arts.

Many Core Knowledge teachers, including many who advocated "inquiry", emphasized the importance of test preparation and teaching students scientific facts and vocabulary. Nearly half (46 percent) of the Core Knowledge teachers who participated in this study mentioned test preparation as an aspect of their science teaching and twenty out of the thirty-five (57 percent) explicitly mentioned the teaching and learning of scientific facts when discussing their approach to science instruction. Indeed, many teachers highlighted such fact learning as a primary goal of their science instruction. One veteran teacher noted, for example, that she finds multiple ways to present and review each topic in the sequence throughout the school year. Asked to give an example, she described several activities her 5th grade students engaged in to help them memorize common elements and their symbols. These activities included flashcards, quizzes requiring them to fill in the periodic table, matching games, and "quiz bowl" type games where groups of students competed against one another to recall elements. In discussing these strategies, the teacher notes proudly that "by the end of the year, they know it… I mean, really know it so they won't forget once they get to chemistry. If you ask them what element is Au or what is the symbol for Sodium, they'll get it" (Interview, 4/7/11). When I asked whether she thought students knew anything about the elements beyond the names and symbols, she stated that "we don't really have time to get much deeper, we don't do any labs or anything regarding it, but I think we give them a pretty good foundation." Similarly, a teacher at another Core Knowledge school draws a distinction between *knowing* scientific facts and the ability to *do science* stating that "Our kids know science – they can tell you the facts on the test and some of them know a whole lot actually…wouldn't be surprised to see them on Jeopardy - but I don't think they get to actually *do* science, if that makes sense..." (Focus Group, 2/23/11). This teachers' statement reflects what seemed to be a common view among Core Knowledge teachers - that *knowing* science and *doing* science were different objectives and knowing scientific facts often took precedence over the ability to engage in authentic scientific inquiry.

In contrast to the somewhat traditional approach to science teaching described by many participants, there was a sub-set of Core Knowledge teachers whose perspectives much more closely resembled "reformed" science teaching. Rather than prioritizing the transmission of content from teacher to student, there were some teachers who highlighted the importance of student-directed inquiry. For example, one teacher describes her view on student science learning and her role as a resource for students, saying (Interview, 3/14/11):

> My students have always learned best when they could explore and were able to ask lots of questions. Children are curious about their world, and want to know how things work and why. One of aspects of success for me is to create an

environment that fosters curiosity in the children." Similarly, one survey respondent notes that students learn best "by actively doing instead of reading or being talked to. I define success in science when students can connect to the real world and be able to explain it in depth.

One of the most common science teaching practices reported by Core Knowledge teachers was the integration of science with other subject areas. A full 71 percent of Core Knowledge teachers reported that their science instruction involves some sort of integration across subject areas. Sixty-three percent specified that they integrate science with math and fifty-seven percent indicated that they integrate science with literacy. Interestingly, integration across subject areas was reported both by teachers who employed more traditional approaches to science teaching and by teachers who focused more on student inquiry. Teachers in the former category tended to note that integration was a time-saving strategy and describe how students completed assignments in mathematics or reading/language arts that related to the science standards, such as science non-fiction texts or stories related to science content. Teachers who focused on inquiry explained how student project and activities often involved inquiry in multiple subject areas. For example, one third grade teacher described how her students spontaneously drew connections between mathematics, literacy, and science during a unit on plant growth (Focus Group, 3/10/11):

I planned to have students make observations of the plants and tell how they change as they grow. Of course, we took measurements so that linked in with the math, but the kids really wanted to apply it more to math and they had the idea to

> do line graphs and later when we were writing story problems for each other, they wanted them to be about their plants.

Because the Core Knowledge reform model does not provide guidance on science teaching practices, whether the tendencies among participating Core Knowledge teachers can be attributed to the reform model remains unclear. That said, a number of teachers did refer to the model, and particularly to the Core Knowledge sequence, as rationale for the choices they made regarding their science instruction. For instance, one teacher discusses how the Core Knowledge model influenced her decision to focus more on the acquisition of knowledge than inquiry (Interview, 4/7/11):

> I used to want to do more inquiry type experiments, really let the kids get in and experiment. But we don't always have time and what Core does is make it clear that all kids should know x, y, and z - so that's what you focus on… you can still do the labs, but its more about helping them study and giving them the information they need so they know as much as they can about science.

This perspective implies that knowledge is "given" by teachers to students and that the process of developing understanding of scientific concepts does not necessarily require inquiry on the part of the student. Thus, at least some Core Knowledge teachers seem to have internalized the model's emphasis on content over the processes of science learning. At the same time, for teachers who are inclined to integrate science with other subject areas or pursue a more inquiry-oriented, student-driven mode of science instruction, it does appear that the model is flexible enough to accommodate such reformed approaches to science teaching.

Teaching Practices in International Baccalaureate Schools

Observed Science Teaching Practices. Science lessons were observed each of the three days I spent in one International Baccalaureate School. The three lessons occurred during the third week of a six-week-long unit on the topic of natural disasters. Although each day's science activities were evaluated separately using the RTOP instrument, students were engaged in inquiry activities that spanned several school days. Specifically, during the week observations were conducted, students were working in small groups on an inquiry project in which they investigated and created models illustrating the causes of natural disasters. Prior to the lesson, the teacher explained that the project had been presented to students as a problem-based learning task. Students had been told that the U.S. Government was working on new plans to address natural disasters, but they needed more information on how different natural disasters happen. Within this context, students would be working as "consultants" to research natural disasters and share their findings with government officials.

On the first observation day, the lesson began by the teacher asking each group of student "consultants" to share which natural disaster they decided to investigate, indicate the 2-3 questions their group would focus on exploring, and describe the methods they would use to research their questions. Students then spent the remainder of their class time conducting research using a variety of resources including books and articles brought in by the teacher, websites, and textbooks. Several students wrote emails or made phone calls to local agencies, national organizations, and family members who had experience with natural disasters. With approximately 15 minutes remaining in class, the teacher asked students to have a meeting with their consulting groups to share the most interesting things they had learned about their natural disaster. Each group of students were instructed to post their key findings on a poster-board that they would continue updating and share at the class's mini-conference at the end of the week. During the second day of the project, students continued their research and began planning for the disaster models and disaster plans they would be creating the following week. In addition to the resources students used the previous day, the school librarian visited the classroom and met with each group to help with their research. The librarian also brought a series of videos related to natural disasters that students could check out and watch. During the third day of observation, students continued their research and updated their findings for a "mini-conference" in which they shared their findings to other groups and students who visited form a neighboring classroom.

Taken together, the science lessons observed in this International Baccalaureate classroom exemplified many features of reformed science teaching. The lesson was designed to build upon students' prior knowledge and to engage students in multiple modes of investigation and problem solving. Students had ample opportunity to make connections to other disciplines and to real-world phenomena. Although the teacher provided a general topic area, somewhat structured task, and guidance and resources for student investigations, the science learning activities and discourse in the classroom were largely student driven. Students generated their own questions and hypotheses for the investigation and devised a means for testing them. When I debriefed with the teacher after the final lesson, she commented on her students' ability to guide their own inquiry and noted that students often generate questions and creative research strategies that she may not have thought to include in a lesson plan. As an example, she pointed to one group of students who focused their investigation on the question "Are earthquakes related to the weather?" The group sought the help of the school librarian to access online data about the timing and magnitude of earthquakes and weather records and investigate whether any patterns existed. This type of student-driven investigation meant that the majority of the scientific discourse that took place throughout the lesson was in the form of "student-talk". In addition to extensive group collaboration, the teacher created several opportunities for students' to engage as members of a learning community, including sharing the findings of their investigations with students in other groups and even students who visited from a neighboring classroom. Instead of seeing herself as a more knowledgeable lecturer, the teacher saw her role as that of resource person and listener. In our discussion following the lesson, she notes (4/28/11):

> It's not just about giving them information - anybody can read to them or stand up there and tell them about earthquakes and volcanoes… for me its more about getting them to think and question and really grapple, think even if they get confused or something, even if they get it wrong at first, at least it's with the ideas on their own, so, I mean I think that's how they really learn it.

Reported Science Teaching Practices. Teachers from the two International Baccalaureate schools that participated in this study reported their science teaching practices in interviews, focus groups, and through open-ended survey items. Although teachers from one of the two schools who participated in school focus groups and many survey respondents describe "reformed" teaching practices that closely resemble those observed in the IB classroom described above, teachers from a second school, which had more recently adopted the model, reported much more traditional science teaching practices. Table 6. presents the frequency with which all IB teachers' comments were coded according to each of the RTOP indicators along with additional codes that emerged from the analysis of teachers reported teaching practices. Table 7 presents the frequency of teacher responses by school to illustrate differences between the two IB schools that participated in focus groups and interviews. Across schools, teachers implementing the IB model highlighted student engagement in hands-on activities and inquiry and the integration of science with other subject areas as science teaching practices that occur in their classrooms. Additionally, a high proportion of teachers in one IB school emphasized a number of RTOP indicators suggesting that science lessons in their classrooms tend to be explicitly student-centered, with lessons building on students' prior knowledge and driven by student inquiry.

The IB model's emphasis on interdisciplinary learning was clearly reflected in IB teachers' comments regarding the integration of science with other subject areas. Seventy-five percent of IB teachers who participated in this study described integrating science with other subject areas. Sixty-four percent report integrating science with literacy, and sixty-one percent reported integrating science with mathematics. Most frequently, IB teachers reported integrating science with other subject areas in the context of interdisciplinary units developed in collaboration with other teachers at their schools. Within focus group discussions, teachers described a variety of units they had designed over the years on a range of topics including Natural Disasters, Poetry, the Five Senses, the Four Seasons, Justice, and Conservation. Teachers noted that although science concepts are addressed within each unit, the degree to which science is integrated tends to vary depending on the topic of the unit. For instance, one survey respondent who describes her approach to science teaching as "holistic" states that:

> It depends on the unit, you can find science in just about anything, but sometimes it's a unit more based on English or Social Studies. So, as an example, we do a poetry unit - kids definitely have the chance to write poems to express their science ideas and we tie it in how we can, but in that unit we do tend to do more with English, obviously, and sometimes a lot more neat activities with Social Studies.

When discussing their motivation to integrate science with other subject areas, teachers noted that they believed an interdisciplinary approach was more conducive to student learning, that it was more engaging for students, and that it enabled them to make connections to "real-world" issues and teach science in a more "authentic" way. For instance, one IB teacher expresses his view on interdisciplinary learning stating (Interview, 3/17/11):

> I don't think that, well that there is any other kind, really. We've invented these boxes and labeled them with Math and Science and Social Studies, but that's so artificial, you know, really pretty fake since it doesn't mean that much, really, since real knowledge, the kind we want our kids to have, is connected. You can't just teach one thing in isolation and expect them to really, truly get it… at least not on a deep level.

Although teachers in both schools report this type of integration across subject areas through interdisciplinary units, as indicated in Table 7, teachers at School A reported integrating science with other subject areas at a higher rate than teachers at school B. Teachers at school B attributed their difficulty enacting interdisciplinary units both to uneven implementation of the reform model across grade levels within School B and the relatively short duration of the school's implementation of the IB model. In their school focus group session, teachers at School B disclosed that certain grade levels had embraced the IB model more fully than others. Specifically, teachers reported that while most grade levels were "at least experimenting" with interdisciplinary units, their 5th grade remained completely departmentalized with students attending separate mathematics, science, english/language arts classes each day. Asked whether it was possible for teachers to teach interdisciplinary units within this type of departmentalized schedule, one fifth grader teacher stated "well, it might be possible but we don't do it, at least we haven't yet… there's just too much pressure to get them ready for 6th and it was a process to get where we are with each teacher having their specialty, so I'm not sure we can risk it at this point" (Focus Group, 3/24/11). In spite of this unevenness with which teachers integrate science with other subject areas, teachers clearly endorsed interdisciplinary science teaching as a worthy goal. For instance, one first grade teacher praised her second grade colleagues for their efforts (Focus Group, 3/24/11):

> Second grade has it going on. They've really worked on the units and I think they've pretty much figured what IB is about. I see all the great stuff they are doing and I feel better about moving forward even if my grade isn't on that level yet.

A similar pattern emerged with regard to teachers' enactment of student-centered science instruction. While a high proportion (72%) of teachers across IB schools reported that their science lessons were student-driven, this approach to science teaching and learning was particularly prevalent among teachers at School A where nine out of the ten teachers who participated in interviews or a focus group discussion described science instruction that was explicitly student driven. In contrast, four out of ten teachers at School B reported student-directed science lessons. One particularly interesting discussion regarding this aspect of science teaching occurred among three teachers at School B as they describe an actual visit they made to School A. Earlier in the year in which the study took place, a small group of teachers from School B spent a day visiting classrooms at School A. (Note that teachers at School B were not informed that School A was also participating in this study; they mentioned the name of the school spontaneously in their discussion). The goal of the visit was to give teachers an opportunity to observe and speak with experienced IB teachers about the strategies they use for lesson planning and delivery. Although teachers reported seeing some commonalities in their science teaching and that of the IB teachers at School A, teachers highlighted a clear difference in the degree to which science lessons were student centered at their school versus School A. One teacher offered the following summary of her observations at School A (Focus Group 3/24/11):

> This was a textbook IB school, but if I didn't know what an IB school was, I would know that it was kid centered at the very least. Clearly, kids were running the classroom. Like the teacher was very much letting them explore. I mean it was really… it was very interesting to see that because it's so different from where we're coming from. And to see where their priorities were. Their priorities were really with the process and with kids asking their questions and figure out how to answer them. I would say. Umm, it was showing growth, there were a lot of kids doing their own things. And the teacher just sitting back and watching and observing and sometimes asking questions but mostly letting the kids figure

> it out on their own… I felt like it was very much so umm, it was very different feel… a different atmosphere.

This teachers' characterization of science teaching practices in another IB school in comparison to her own school is consistent with between-school differences that emerged from an analysis of teachers' surveys, interviews, and focus group discussions. In contrast to teachers who are just beginning to implement the IB model, experienced IB teachers were more likely to report that their science lessons were designed or revised according to students' questions and ideas, that students frequently designed their own inquiry activities, and that students often initiated and determined the direction of science discourse in their classrooms. Consider, for instance, one experienced IB teacher's description of how she believes students best learn science (Interview 3/17/11):

> I find that students learn science best through discussion and investigation. When science relates to what students already know and piques their curiosity, the level of engagement increases. When students are engaged, they tend to talk and participate more fully. They take risks. I've found that students learn best when they "discover" a property of something or come up with a conjecture on their own. This type of learning is authentic; they never forget it.

Here, the teacher not only explicitly values students' prior knowledge and participation in scientific discourse within a learning community, but she also cites student driven inquiry (i.e. a student discovering a property or coming up with a conjecture on their own) as important for fostering student learning and engagement in science. This perspective was shared with several other IB teachers who highlighted inquiry as an indispensable aspect of science learning. Although there were two less experienced IB teachers who characterized student inquiry activities as enrichment intended to reinforce science content learned in other ways (i.e. reading science texts, teacher presentation), the majority of IB teachers described inquiry as a primary method by which students build understanding of science content.

In addition to providing a strong endorsement for student inquiry, many IB teachers, and especially those with ample experience implementing the IB model, discussed the role that students' questions play in their science instruction. For instance, one teacher at School A describes the important role that questioning plays in her classroom (Interview 3/17/11):

> Asking questions never gets old. That's one of the keys with IB. The more you ask, the more they usually want to know why for themselves….and more important than the questions I ask them really are the questions they ask to each other, the questions they ask themselves. Asking those questions and figuring out what to do, like how to answer them is what my kids love, they really get into that.

Similarly, one survey participant elevates the importance of student questions, describing a successful science lesson as "one in which a question is answered and many more are uncovered. A learner has truly grasped a concept when he or she can pose new questions on the subject". Several teachers attributed this emphasis on student questions directly to the IB model, and one teacher noted that "curiosity is one of the 'attitudes' in the model, one of the main things we really focus on" (Focus Group, 2/4/11).

In conclusion, while IB teachers who participated in this study reported a range of science teaching practices, reformed science teaching practices were commonly reported among teachers with experience implementing the IB model and were observed in one IB teacher's classroom. As evidenced by testimony from teachers at a school that has only recently began implementing the IB model, reformed science teaching does not necessarily follow from a school's decision to adopt the model. It is quite possible for individual teachers or grade levels to resist the transition from a more traditional approach to the more student-centered, inquiry oriented approach encouraged by the IB model. However, many teachers with experience implementing the IB model report science teaching practices, such as the integration of science with other subject areas and empowering students to ask and seek answers to their own science questions, that are clearly consistent with reformed science teaching. Further, when asked to describe their motivation for engaging in such practices, many of these teachers attributed their approach to science teaching to the IB model. Thus, the interview, focus group, and observation data reported here provide strong evidence that when fully implemented, the IB model is likely to promote reformed science teaching.

Science Teaching Practices Across Reform Models

Through focus group discussions, interviews, survey responses, and classroom observations, a number of important variations in science teaching practices emerged across reform models. Among the science teaching practices that tended to vary across reform models were 1) the integration of science with other subject areas, 2) the degree to which science is student versus teacher centered, and 3) the extent to which science instruction focuses on traditional science learning goals such as mastering "science facts" and vocabulary versus attaining conceptual understanding. Results pertaining to each of these variations in science teaching practices are synthesized across reform models below.

Integrating Science with Other Subject Areas

As indicated in Table 6., the degree to which teachers reported integrating science with other subject areas varied across reform models. Whereas teachers in the International Baccalaureate and Core Knowledge schools commonly reported integrating science with other subject areas, this strategy was quite rare among Direct Instruction teachers. Although teachers in Direct Instruction schools reported that they had developed and implemented interdisciplinary units prior to their school's adoption of the reform model, they contended that DI's scripted model prevents meaningful integration of science content with other subject areas. This lack of integration contrasts with reports from teachers in Core Knowledge and International Baccalaureate Schools, where the majority of teachers reported integrating science with other subject areas. Data reveal a possible pattern in teachers' motivation to integrate science with other subject areas - teachers who described more traditional science teaching practices tended to describe integration as a time-saving strategy and a way to make connections across content areas in order to adequately cover science standards. While these benefits of integration were recognized by some teachers who reported more inquiry oriented or "reformed" teaching, these teachers also highlighted the extent to which integration across subject areas enhances student understanding of science content. This perspective was particularly common among teachers with experience implementing the IB model.

Student-centered vs. Teacher-directed Science

There were also clear variations in the extent to which teachers' observed and reported science teaching practices were student-centered versus teacher-directed. Although teachers in all three reform models used terms such as "inquiry" and "hands-on activities" when describing typical science lessons in their classrooms, when asked to provide further detail it became clear that many teachers prefer a teacher-directed approach to more student-centered science instruction. Specifically, in classroom observations and teacher reports of their science practices, Direct Instruction and Core Knowledge teachers tended to disregard students' prior knowledge and questions, limit "student-talk" and student contributions to scientific discourse, and provide few opportunities for students to be design or determine the direction of inquiry activities. Although teachers who are relatively new to the IB model also reported some of these more teacher-directed practices, experienced IB teachers clearly articulated a student-centered approach to science teaching in which lessons and inquiry activities flow directly from students' questions and students are empowered to design investigations in order to explore their questions and ideas. This student-centered approach reported by experienced IB teachers is consistent with observation data gathered in one IB classroom.

Traditional Science Learning Goals vs. Inquiry and Conceptual Understanding

Consistent with the differences in student-centered versus teacher-directed teaching described above, variations in teachers' goals for their science instruction were apparent across reform models. Teachers in Direct Instruction schools emphasized the importance of learning science vocabulary and were unlikely to discuss science learning in terms of conceptual development. Similarly, consistent with the model's goal of equipping students with the knowledge they need to be "culturally literate", teachers in

Core Knowledge schools tended to prioritize the acquisition of vocabulary and "scientific facts". Teachers in these models tended to describe experiments and hands-on activities as ways to enrich or reinforce student learning rather than a the means by which learning is achieved. Again, these same tendencies were expressed by some teachers who are relatively new to the IB model; however, teachers from schools that have fully implemented the IB model described student inquiry as the centerpiece of the science instruction and crucial for fostering students' understanding of science concepts.

Research Question 2: Allocation of Time for Science Education

In both the extant literature (Spillane et. Al, 2001; Pringle & Carrier-Martin, 2005) and the quantitative pilot study that informed this dissertation, time is a critical yet often scarce resource for science teaching and learning. This study examined the allocation of time for science education activities within and across the Direct Instruction, Core Knowledge, and International Baccalaureate reform models. In addition to teachers' estimates of the amount of time spent on science education, I documented teachers' accounts of how time was allocated within the school day and the academic year and any factors that may have limited time for science instruction. Additional data pertaining to the allocation of time for science instruction was obtained through observations at one school implementing each reform model. Teacher estimates of time allocated for science education from each data source (interviews, focus groups, open ended surveys) are presented by reform model in Table 8.

Time Allocation and Direct Instruction

Across data sources, teachers in Direct Instruction schools reported that time for science activities was scarce at their schools and identified the Direct Instruction reform model as the primary factor limiting time for science instruction. Direct Instruction teachers who participated in the study reported teaching an average of 2.1 science lessons each week. The average length of a science lesson reported by teachers in Direct Instruction Schools was 21 minutes and teachers estimated that they spend an average of 53 minutes on science instruction weekly.

Indeed, documents detailing recommended scheduling for Direct Instruction classrooms clearly reflect the prioritization of time for the reform model over time for other subject areas, including science. These guidelines state that "one of the most important prerequisites for implementing the comprehensive Direct Instruction model successfully with all children is to provide sufficient instructional time for each instructional group" (NIFDI). This document, available on the National Institute for Direct Instruction's website, goes on to recommend that DI school schedules should include: a 90 minute reading block each morning for all students, a 60 minute reading block in the afternoon for students in grades K-2 and students reading below grade level in grades 3-5, and an additional 60-minute block for language instruction for all students. Sample schedules provided for First Grade classrooms recommend Direct Instruction activities from 8:30 – 10:30 each morning and 1:00 – 2:15 each afternoon, reserving the three-hour period between 10:30 am and 1:30 pm for "Other Activities: Lunch, Recess, Science, Social Studies, Math, PE, Art, etc.". Similarly, the sample schedule for second through fourth grade recommends approximately 2 hours each morning and an hour each afternoon for Direct Instruction and reserves one afternoon hour for "Science, Social Studies, or P.E.".

According to school schedule documents, both Direct Instruction schools participating in this study follow a version of the D.I. recommended schedule: two hours of Direct Instruction programming is scheduled for the morning and an additional hour is scheduled for the afternoon. Additionally, both schools schedule one hour each day for math instruction, 45 minutes for foreign language programs, 30 minutes for lunch, and 30 minutes for "specials" (art, computer lab, P.E., library). Students do not attend recess. Although this schedule includes approximately 45 minutes for science and/or social studies daily, teachers' estimates of time spent on science and their description of the allocation of time for science suggest that these school schedules may overestimate the amount of time available for science. When asked about the discrepancy between their estimates and the intended school schedule, teachers provided several reasons that scheduling 45 minutes each day for science and/or social studies was unrealistic in their classrooms. In both schools, teachers reported that because the Direct Instruction curriculum is not necessarily aligned to the State Standards and may not include concepts that appear on state standardized tests, during the months leading up to testing, much of the time reserved for science and social studies is spent on test preparation. Additionally, teachers in both schools pointed out that the block of time intended for science and social studies is scheduled for the end of the school day and that assemblies, announcements, and preparing students for dismissal inevitably steal time intended for science and/or social studies. One teacher emphasizes that she tries to "cram" science in at the end of the day but is often unable to enact her lesson plans (Interview, 4/21/11):

> You know what a classroom is like at the end of a school day. By the time we finish Reasoning and Writing, its 2:30, maybe 2:35. 18 6-year-olds need to be

> lined up, ready to go home with homework folders and behavior notes and coats before they start afternoon announcements. Even if I get everything ready during my planning or lunch and it goes smoothly, by the time we get half way through it and kids are just really getting into the activity I'm looking around and seeing that we only have a couple minutes 'till we have to clean up. Doing a good job with science takes so much time and we just don't have enough.

This teacher account corresponded with the allocation of time for science that occurred during the three-day observation period at one DI school. Although the teacher participating in the observation had shared 2 lesson plans calling for a total of ninety minutes of science instruction during the three day period, only a 22-minute portion of one of these lesson plans was taught at the end of the first day. The teacher had prepared an activity related to a reading from the science textbook, however after students completed the reading and engaged in a brief discussion, the lesson was cut short by the school's dismissal procedures. When asked about the reason these lessons were not implemented, the teacher stated that "as usual, I just ran out of time" (5/3/11).

Maintaining the "Illusion" of Science Instruction. Focus group participants in both of the Direct Instruction schools described how the limitation of time for science remains unacknowledged at their schools even as they are expected to fulfill many of the requirements of science teaching. In spite of severely limited time for science, teachers reported that they are expected to create weekly science lesson plans, attend district professional development sessions, and create bulletin boards featuring student work in science. One teacher at the school implicates the Direct Instruction reform model in the limitation of time and reflects on her school's requirement that teachers submit weekly lesson plans in spite of limited time for science (Focus Group, 3/9/11):

> Before DI, I'm not saying that we had enough time for science, but it was at least possible to find an hour or two here and there. You could plan science lessons and have some faith that you could actually do it. Ever since DI, it's just for show, it's kind of like an illusion we all keep up. Every week, we make the plans… sometimes we bring in the labs, but we already know that there is no time. It's pretty pointless if you ask me.

A teacher at the same school elaborates, expressing her frustration with the way in which her school fails to acknowledge the lack of time for science (3/9/11):

> She's totally right. It's sad – for us 'cuz we do all the work and planning and training and… but, well more sad for the kids. They let us have time to put up something real uh impressive for our boards … so people who come through think there's some science happening, but if you just do the math and add up all the hours we have for DI and everything else…like lunch and math and specials, its pretty obvious that science is left out.

These sentiments were corroborated by teachers at each school who participated in interviews. One teacher, in particular, began her interview by stating that she was glad to talk to me because she believes that "people need to know the truth about what is going on" (4/6/11). When I asked her to describe a typical science lesson in her classroom, she replied that a typical science lesson "would look like a typical reading lesson." Asked to elaborate, she said that although she tries to "do something hands-on" at least once each week, her students' exposure to science content was limited primarily to science concepts that occasionally "pop up" in the stories they read for the Direct Instruction Reading Mastery program. As the conversation continued, this teacher noted that the most valuable science activities her students engage in occur after school or at home, primarily through projects students complete with the help of their parents or guardians. She goes on to describe her mixed feelings regarding these projects:

> Overall, they are a good thing. We can't do much or sometimes any in class, but at least they do a little something at home… and I think its good to get parents and grandparents involved… but there's still some issues with it. Mainly, it's not enough. There's only so much kids can do at home and some don't have what they need like supplies or the support from family to know what to do and who knows if their families can answer their questions or not. We shouldn't expect that parents can do my job. They should get to do science in school. So, the other thing is that these are projects we are supposed to do with kids in class…they tell us to post them up and pass it off like some great thing's going on in here but its not really like we are a school that does all that much when it comes to science.

Integrating Science with Other Subjects. Teachers who participated in focus groups, interviews, and the online survey commonly stated that integrating science with other subject areas would be an effective teaching strategy and one they have used in the past. However, when asked to describe their current science teaching practices, none of the teachers implementing the Direct Instruction reform model mentioned integrating science and other subject areas. Indeed, teachers insisted that Direct Instruction's scripted program makes such integration difficult if not impossible. "How do you mix science in if you are going by a script?", asked one teacher during her school's focus group session (3/31/11). A colleague replied “Well, you can’t. Not really. I mean, if you stop the lesson and do your own explanation you can bring some of it in, maybe answer a question related to science… but we saw how we can’t do CBU stuff with DI.” Asked to elaborate and describe the “CBU stuff” they would have done if not for Direct Instruction, teachers described a district wide initiative that involved using a backward design process to develop thematic interdisciplinary units. Two 1st grade teachers gave the example of a Concept Based Unit they developed several years ago in which students learned science, mathematics, reading/language arts, and social studies standards by completing interdisciplinary projects related to the theme of conservation. In the following exchange, the teacher elaborates on the unit and explains how Direct Instruction prevented its implementation (Focus Group 3/31/11):

> Teacher: We made this unit with so many of the science concepts in the standards but still a lot of reading and writing and kids did math and science at the same time like when we had them do a recycling project and they counted and estimate the cans as they came in and then tied that to lessons on decomposition where we experimented to see how long different things took to decompose so then students could use science to think about why we recycle.
>
> JG: And you don’t use this unit any more?
>
> Teacher: No. Not with D.I. There’s no time to do it like we planned it. So, yeah,

no. There’s times in the year, especially after tests and if the kids are getting through enough lessons then we pull out some pieces of it and do that on top of DI , kind of use the unit for a resource, but there’s no way we could integrate the CBU with DI. They just don’t go together.

Teachers' accounts of the degree to which science is integrated into Direct Instruction reading and language arts programs contrast with the following claim accompanying recommended schedules published on the National Institute for Direct Instruction's website (http://www.nifdi.org/15/model-components/scheduling-sufficient-instructional-time accessed on 2/12/11):

> Note that students who receive two reading periods a day will learn a great deal of science and social studies information. Science and social studies concepts are systematically pre-taught in the upper levels of the Reading Mastery program, integrated into the stories and then reviewed to ensure students' retention of the material. Some schools have used no other science program, and their students have performed outstandingly on tests of their scientific knowledge.

Beyond this statement, NIFDI provides no evidence and there are no published studies to substantiate the claim that Direct Instruction students learn " a great deal of science and social studies information" or that students in Direct Instruction schools perform "outstandingly on tests of their scientific knowledge". Although teachers in the upper grades did confirm that their students' Direct Instruction reading assignments often include science content, they unanimously agreed that this degree of integration was insufficient given their goals for their students' science learning. Specifically, teachers noted that the science content included in Direct Instruction lessons was often not aligned with State Science standards, provided only a superficial overview of unrelated topics, was occasionally inaccurate, outdated, or oversimplified, and did not build upon students' prior knowledge in science. Teachers also contended that, while the science material included in the Direct Instruction lessons could enable students to acquire certain scientific facts, the portions of the program that include science content remain teacher directed and do not afford opportunities for students to engage in the type of inquiry activities advocated by the district's science initiative.

Time Allocation and Core Knowledge

Participating teachers implementing the Core Knowledge reform model had a variety of perspectives regarding the allocation of time for science education. Major themes articulated by Core Knowledge teachers included the scarcity of time for science, the implications of accountability policy (i.e. standardized testing, NCLB) for instructional time in science, and the integration of science with other subject areas. Qualitative evidence pertaining to each of these themes is presented below.

Scarcity of Time for Science. In both focus groups and each interview, Core Knowledge teachers attested that time to cover the State Science standards and implement the district's Science Initiative is limited and, to varying degrees, insufficient. Core Knowledge teachers who participated in the study reported teaching an average of 2.9 science lessons each week. The average length of a science lesson reported by teachers in Core Knowledge Schools was 31 minutes and teachers estimated that they spend an average of 88 minutes on science instruction weekly

Interestingly, when speaking about the allocation of time for science, teachers at both Core Knowledge schools spoke specifically about the allocation of time to cover required content versus time for students to engage in inquiry. At school A, both focus group and interview participants stated explicitly that there wasn't time for inquiry activities and any time they found for science instruction was spent teaching students basic concepts and vocabulary (Focus Group, 2/23/11). One teacher at this school agreed, stating “Yeah - we make sure they get the basic ideas, that they know the topics for each grade level but we usually don’t get to reinforce the ideas, like with labs and experiments.” At school B, teachers had a slightly different perspective, describing time for inquiry as a priority that, without careful attention, could be short-changed. In the following exchange, teachers at school B discuss both the importance and the limitation of time for inquiry activities (Focus Group, 3/10/11):

> Teacher 1: When I think of real science, it’s not just the textbook, its actually doing experiments and the essential labs but we don’t always have time for that.
>
> Teacher 2: No. We don’t. So sometimes we are forced to just go with the textbook and discussions which are part of it but I don’t think the kids learn as well.
>
> Teacher 1: Yeah. So we try different things, like integrating science and reading and math or if we get a field trip we try to do something science oriented or have a guest come in, but if we didn’t really try to work in the hands-on activities, all the science time… it would be basically learning from the textbook.

Teachers in neither of the Core Knowledge schools implicated the reform model as a factor limiting time for science instruction. Within each of the focus groups and individual interviews, teachers did not spontaneously mention the reform model and when they were asked to discuss the model, they did not mention instructional time being affected. When asked about how time is allocated within the model, teachers noted that the Core Knowledge sequence isn’t intended to consume all instructional time and that time not devoted to mastering the content in the sequence can be spent on science activities. These statements are consistent with the Core Knowledge

Foundation's claim that the sequence "is not meant to outline the whole of a school's curriculum, but rather to provide a coherently organized plan for content and skills instruction, while remaining flexible enough to not exclude locally determined or other required content and skills" (vi, Intro 2010 Core Knowledge Sequence).

Accountability Policy

Although teachers did not identify the Core Knowledge reform model as a factor limiting time for science instruction, teachers did cite sources beyond the school as limiting time for science education. Of the limiting factors teachers mentioned, accountability policy and, specifically, standardized testing and No Child Left Behind, were most commonly mentioned by teachers at both schools. In an individual interview, one teacher cites No Child Left Behind as a major factor limiting time for science (3/14/11):

> I've been teaching for over 20 years. All kind of programs come and go, but I noticed a big change once NCLB came around, a big change for science and how much we could put into it since it doesn't really count for AYP.

This sentiment was echoed by colleagues in the school focus group, who engaged in the following exchange about the implications of the state testing program for science (2/23/11):

> Teacher 1: I'd say the biggest thing is testing. If we are going to make AYP there's going to be a focus on the subjects that matter.
>
> Teacher 2: True. But I'd say science matters as much.
>
> Teacher 1: Yeah. But matter for the test.

Teacher 2: Right. That's what I think and my kids would probably agree because they love science, but we just don't get to it because the test says it doesn't matter.

Teacher 3: You'll probably see some difference when we switch over 'cuz you know how they are supposed to make science count for AYP soon, next year or so I think. So when it counts and kids have to remember the science for the CRCT if we get AYP, well then we might get more time.

Teacher 1: Maybe. It's just I don't know where we'll find it since we don't do it now. It's not like we will spend less time on math or reading because they will still count.

This discussion illustrates that, when it comes to allocating time for science education, there may be a disconnect between teachers' priorities and the priorities encouraged by accountability policy. Whether science, as a subject, matters enough to deserve substantive instructional time depends not simply on teachers' professional judgment or even the content specified as important in the State standards, but on whether student achievement on science standardized tests "counts" within the current accountability climate. Although this tension between accountability policy and science education was a common concern among teachers implementing the Core Knowledge reform model, there was little evidence that the Core Knowledge model was responsible for the (mis)allocation of time for science.

Integrating Science with Other Subjects. The integration of science with other subject areas was a recurring theme in both Core Knowledge schools. Specifically, teachers repeatedly mentioned integration as a time-saving strategy that enabled them to teach more science content than they would otherwise. Teachers described a variety of integration strategies, the most common of which were reading lessons focused on non-fiction science texts, teaching mathematics concepts such as measurement through science activities, and interdisciplinary homework assignments and projects students complete outside of regular class time.

Teachers identified aspects of the Core Knowledge program that both enabled and limited integration. Because the program lists the specific content within each subject area students are expected to master, teachers were quick to point out that integration is not "built into" the Core Knowledge sequence, but instead at the discretion of individual teachers. One focus group participant described the process of integrating subject areas, stating (2/23/11):

> It's definitely possible. I mean, the sequence is clear for each subject so it's made to be taught stand-alone, each subject by itself… but all you have to do is look for common ideas in different subjects and tie them together.

One colleague, a first grade teacher, gave the following example of integrating across subject areas within the Core Knowledge sequence:

> Here's one way I've done it. In first grade, the Core sequence has patterns and classification as one topic in math and also classifications of animals in science. So, its pretty easy to see the connection and make activities where kids learn both, like they might have a math activity where they continue patterns with animal pictures but at the same time they name the different animal categories, ya know fish, reptiles, mammals and so on.

At this point in the conversation, a fellow first grade teacher interjects to describe a similar scenario in which she integrates the topic of animal classification into her lessons on Aesop's fables. Although such integration strategies were common among Core Knowledge teachers, there were also teachers in both schools who recognized the limits of integration and expressed a desire to do so more purposefully. One interview participant, in particular, stated that "blending science and math and reading doesn't always mean you are teaching any of them any better. It gives you more time and you can say you 'covered it' but you don't get deep enough, especially the science" (3/13/11).

In summary, teachers in the Core Knowledge schools participating in this study clearly expressed a need for additional time for science, emphasizing a particular need for time devoted to inquiry activities. Rather than implicating the reform model as a factor limiting time, teachers were more likely to point to recent accountability policy and standardized testing. Teachers also described integrating science into their teaching in other subject areas (i.e. Mathematics, Reading and Language Arts) as a strategy for maximizing instructional time; however, there were teachers who highlighted the limitations of this strategy.

Time Allocation in International Baccalaureate Schools

Overall, International Baccalaureate teachers reported spending significantly more time on science than teachers in the Core Knowledge and Direct Instruction reform models. International Baccalaureate teachers who participated in the study reported teaching an average of 3.7 science lessons each week. The average length of a science lesson reported by teachers in Direct Instruction Schools was 44 minutes and teachers estimated that they spend an average of 155 minutes on science instruction weekly. Although the overall amount of time devoted to science on a daily and weekly basis was greater in International Baccalaureate schools, there was a clear difference in time allocation between school A, which has implemented the International Baccalaureate model for over 6 years and school B, which was in its second year of implementation at the time of the study. The length of a typical science lesson reported by Teachers at each school was comparable, with teachers at school A reporting that the average daily science lesson of 51 minutes and teachers at School B reporting an typical science lesson lasted 54 minutes. However, teachers at School A reported spending more time on science on a weekly basis, 193 minutes versus 151 minutes at School B, and delivering a greater number of science lessons, 3.9 compared to 3.0 at School B.

The content of teachers' discussions regarding time also differed somewhat between the two schools. Themes articulated by the teachers at school A were the time consuming nature of science teaching and learning, over-crowding of the science curricula, and the benefits of integration across subject areas. Although integration was also a common theme in focus group discussions with teachers at school B, teachers articulated a tension between the integration strategies promoted by the IB model and departmentalization by subject area. Additionally, teachers at school B attributed the scarcity of time for science primarily to accountability policy and standardized testing. The following section elaborates on each of the themes that emerged from data collected at these two International Baccalaureate schools.

Science as a Time-Consuming Subject Area. In both the focus group discussion and individual interviews teachers at school A discussed the time required to teach science effectively. When asked to describe their approach to science teaching, teachers discussed the process of science learning and the view that the time typically provided for science lessons doesn't always allow for this process to unfold. This perspective is evident in the following exchange by two veteran teachers (2/4/11):

> Teacher 1: When you teach science you aren't just giving kids information - if that were the case, we'd have plenty of time. To really teach science, you have to get into what kids already know and give them a reason to rethink it… that takes a lot of time.
>
> Teacher 2: Yep. For example, in first grade we teach the concept of living versus non-living things, you know, what makes something alive. Seems simple, but last year I had kids with a lot of misconceptions - some kids think that anything that moves is alive, other kids think things have to move in order to be alive… one kid told me that plants aren't alive because they don't have moms. (Laughs).
>
> Teacher 1: I wish I could say that we always get kids to understand the most important ideas, but if we don't have time for that we at least get them thinking.
>
> Teacher 2: The key really is giving them a few different opportunities to think through a concept, as many experiences as possible to say 'hey, maybe this or that isn't what I thought it was'.

Similarly, teachers described project- and inquiry-based science teaching as approaches that, while potentially powerful as learning opportunities for students, can be time consuming. For instance, one kindergarten teacher described a task designed to introduce students to the concept of states of matter in which he presented students with a collection of solid and liquid materials and challenged students to sort the items. He commented on the time involved in implementing this sort of lesson, stating that "it's not the fastest way to do it - it's messy and it could take a whole morning if I let it… I could just tell them 'these things are liquids and these things are solid' and sometimes we do do it that way, but for this one it was important to give them a chance to figure it out for themselves" (2/4/11).

"Overcrowding" the Science Curricula. In addition to commenting on the inherently time consuming nature of science teaching and learning, teachers at School A expressed concern about what they perceived to be an overcrowded science curriculum. Specifically, teachers claimed that the expectation that they adequately cover each of the State's science standards each year was unrealistic. In the school focus group, one teacher noted that the current science curricula "includes way too much, way more than you could teach if you are teaching at your best and giving kids a chance to really learn, not superficially 'get it' but really know the material" (2/4/11). Another teacher agreed with this view, stating that the curriculum is "more than a mile wide and not even an inch deep" (2/4/11). Within this discussion, another teacher drew a comparison to science curricula in other countries - "if you look at our science textbooks and you look a theirs, you see a big difference. Some of the countries that do the best, I think those are the ones with less content in there, with the thinnest textbooks." In an individual interview, one third grade teacher who is involved in the review of the newly developed framework for k-12 standards, described the current curriculum as "overly ambitious" but was optimistic about the new standards stating, "I think we're moving in the right direction this time, more emphasis on allowing kids to develop deep understanding instead of just covering as many science concepts as we can cram into a year" (3/17/11).

Integrating Science with Other Subjects. Teachers at School A appear to have embraced the International Baccalaureate model's call for "transdisciplinary" units. One teacher articulated the school's approach (2/4/11):

> There's not really such thing as teaching just science or math or language arts here - I mean, we label them that way when we have to - but we like to think what we are really doing is teaching kids the world, and we all know the world isn't really packaged that way.

Teachers noted that the amount of time they spend on science differed depending on the unit theme. One fifth grade teacher described this variation, stating that "if it's a unit focused on the idea of conservation, we're able to get a whole lot of science in there, but if we do a unit on a concept like "justice", it probably makes more sense to lean toward social studies" (Focus Group, 2/4/11).

In addition to discussing integration in terms of instructional time, teachers described how time was allocated for planning units and lessons that integrate content across subject areas. Grade level teams meet for in-depth planning sessions at the beginning and end of each academic year to review and make any major changes to the themes that guide instruction. Occasionally, members of the school administration or representatives from the International Baccalaureate organization are on hand to assist with these major planning meetings. With initial plans in place, grade level teams establish a schedule of weekly or monthly meetings to jointly develop lessons related to each theme. Teachers noted that in some grades a teacher with particular expertise in one subject area would develop the lessons that "lean" more toward that content area, and in other grades all teachers develop lessons spanning all content areas. Teachers were also quick to point out how much time they devote to instructional planning and noted that this time commitment was especially demanding the first few years the school implemented the International Baccalaureate model. The demands of this instructional planning process are evident in the following exchange between three focus group participants (2/4/11):

> Teacher 1: In the beginning, it felt like we spent more time planning for lessons than teaching them. It was insane.
>
> Teacher 2: Just the amount of planning and time it took to get the units in line with the standards and make sure we are covering everything was huge and that's before you plan a single lesson.
>
> Teacher 1: and add to that the fact that at the standards keep changing, which means we go back to the drawing board and have to put the puzzle together a new way.
>
> Teacher 3: Yeah. It was pretty tricky, especially at first. Now I feel like we've got it down for the most part, its more maintenance - adding things from year to year, maybe trying out a new unit here or there but we have a good base to work from so we don't spend as much time in the planning.

In summary, teachers at school A tended to discuss the allocation of time for science in terms of instructional considerations, such as the nature of science learning, an overcrowded science curriculum, and the benefits and challenges of integrating science with other subject areas through interdisciplinary units. Teachers recognized that the International Baccalaureate program fosters a mode of student-centered teaching and learning that may be more time consuming than more traditional teacher-directed approaches, but they also articulated that this approach aligns with their views on the nature of science learning and their individual teaching philosophies.

Integration vs. Departmentalization. Teachers at school B, which was in its second year implementing the International Baccalaureate model at the time of this study, described ongoing tension between the departmentalized school schedule in place at the school prior to adopting the model and the interdisciplinary units called for by the IB program. When asked what science teaching advice she would give to a new teacher at the school, one teacher commented on the departmentalization versus integration issue, stating (3/24/11):

> I would say, I mean kind of what we were just talking about, I mean so we are in an IB school, right? So ideally we go to these trainings and we are told, "We are integrating everything. Right? Like the IB philosophy: you teach this unit. So there shouldn't be such thing as a dedicated science block. There shouldn't be a social studies block, etc. Time isn't divided up that way now. So that's what we are told to do. But the reality is, is that we have a schedule we are used to and we know it works and we have to have a science block. So, I think I would tell them that…I would tell them about how you have to strike that balance.

When asked to elaborate on the ways in which the implementation of the IB model has affected the allocation of time for science, teachers continued to describe how their continued departmentalization falls outside the model's recommendations (3/24/11):

> Teacher 1: I want to say that first of all, we are technically an IB school but we actually lied in our application process. We don't do it correctly. I mean they

told fifth grade, “Shut it down. Oh no, we don’t do departmentalized.” Because just like she said, that’s not the IB way.

Teacher 2: Umm, they were told, fifth-grade was told, “Pretend like we don’t departmentalize”, like when they come around, or when we go to the trainings. But, umm, well we do. That’s a lie.

Teacher 1:Right…like we said the whole unit is supposed to be taught as a whole and it’s supposed to be inclusive. You’re not supposed to have a science block. You’re not supposed to have a reading block. You’re supposed to be reading all about what you are learning about in science and social studies. They are supposed to relate, you know. I get why that is the best way and that we’d probably get more time that way, but we don’t do that.

Asked to clarify whether this reluctance to integrate was isolated to the 5th grade, one second grade teacher noted that she saw the same pattern in her grade level stating, “just cuz the kids don’t move from class to class, we’re still doing each subject by itself. Some teachers and grades are doing the units, but not all the time, and we have the bulletin boards, but that’s it really.” Thus, School B appears to be in the beginning stages of the transition from teaching core subjects discretely to developing and implementing the interdisciplinary units required by the IB model.

Accountability Policy. While teachers at school A expressed concern that they couldn’t always find the time required to teach science effectively, teachers at School B contended that time for science was limited because of a focus on other “high priority” subject areas. Within both the focus group and individual interviews, teachers described the implications of accountability policy and, specifically, the state’s standardized testing program, for the allocation of time within the school day and across the academic year. One teacher described the scarcity of time for science in her classroom, stating that (Focus Group 3/24/11):

> I think I definitely struggle with time, I mean during the day. Like science and social studies would be what's cut instead of reading and math since that's what's on the test, that's what we care about most. I learned my first year, even if it says we do science every day, there's just no way - you just fit it in when you can. I spend, because of our specials schedule, I have a huge afternoon gap on Thursdays and Fridays. So we usually do science on Thursdays and Fridays where we can do an experiment and then read a lot about it. So I would say like 30 to 45 minutes twice a week.

Two other teachers concurred, with one regretting that "it's so sad how there's no time to really get it in. It's so hard to get it in" and the other adding "because there's this big push where they have to pass reading, they have to pass math. There really isn't time. At least until after the CRCT." The discussion of the allocation of time for science across the school year continued, with the teachers agreeing that the standardized testing schedule leads to the prioritization of teaching and learning in tested subject areas. One interview participant described the effects of the test preparation calendar noting (3/31/11):

> This gets tied in with the CRCT calendar that you know, everything has to be taught by January. And then you have February and March to review and you take the CRCT in April. For lots of teachers who are afraid of their kids not

> meeting, science and everything else that isn't on that test or doesn't count for AYP and promotion gets pushed to the end.

Although this study focuses on comparing aspects of elementary science education across reform models, important differences between the two International Baccalaureate schools participating in this study highlight the uniqueness of individual school context. In particular, while the study does not focus on demographic data or differences in student populations between the schools, it should be noted that the participating International Baccalaureate schools serve students at opposite ends of the socioeconomic spectrum. The most experienced International Baccalaureate teachers in this study teach at a school where 80% of the student body is White and only 6% of students are eligible for free and reduced lunch. In contrast, at the school where the International Baccalaureate model is implemented during the previous two school years, 69% of students are eligible for free and reduced lunch and the student population is 98% African American. There are also clear differences between the schools with regard to their standardized testing context. For years, School A has consistently ranked among the top schools in the state in each measured area of standardized tests, a fact that may explain why teachers at this school tended to express relatively little anxiety about preparing students for the State's standardized tests. Although School B has repeatedly met their Annual Yearly Progress targets and has tended to score fairly well relative to other schools in the district on the State test, a recent investigation implicates school administrators in a serious cheating scandal and calls the validity of these student performance results into question. The investigation also substantiates teachers' claims that they were pressured by administrators to "do whatever it takes" to meet AYP targets.

At this school it appears that part of "doing whatever it takes" likely includes neglecting science in order to focus instructional time on tested subject areas.

In summary, International Baccalaureate teachers at the two schools participating this study recognized the value of the model's emphasis on integrating time for science teaching and learning with other subject areas through interdisciplinary units; however, it appears that this goal of integration was internalized and enacted in School A whereas School B continues to negotiate a tension between the integrated approach of the IB model and departmentalization. There were also clear differences in the causes teachers cited for a scarcity of time for science. Teachers in school A attributed limited time to the nature of science teaching and learning and what they perceived to be an over-crowding of the science curricula. In contrast, teachers at school B attributed the scarcity of time for science primarily to accountability policy and standardized testing.

The Allocation of Time for Science Across Reform Models.

Through focus group discussions, interviews, and the analysis of school reform model documents, a number of themes regarding the allocation of time emerged within and across reform models. Among these themes were 1) the scarcity of time for science education, 2) the effects of accountability policy on the allocation of time for science and 3) the integration of science with other subject areas. Results pertaining to each of these themes are synthesized across reform models below.

The Scarcity of Time for Science. As illustrated in Table 8, clear differences exist in the allocation of time for science across reform models. Indeed, to varying degrees across reform models, teachers commonly described a scarcity of time for science education in their schools and classrooms. Although teachers tended to agree that time for science was limited, there were clear differences across and within reform models regarding the factors teachers believed to be responsible for limited science time. Interestingly, only teachers in the Direct Instruction schools directly implicated the model as a factor limiting time for science education. In contrast, teachers in the Core Knowledge schools tended to explain the lack of time for science as a consequence of accountability policy and standardized testing requirements. This perspective was shared by teachers in one school in its second year implementing the International Baccalaureate model; however, teachers in the school with more International Baccalaureate experience discussed the scarcity of time for science in terms of instructional considerations, such as the inherently time consuming nature of science learning and the challenges of teaching an “overcrowded” science curriculum.

Accountability Policy. Accountability policy, and specifically, pressures to attain Annual Yearly Progress (AYP) and prepare students to excel on standardized tests, were common concerns that emerged in teachers’ conversations about the allocation of time for science education. Interestingly, although the same accountability and testing policies apply in all participating schools implementing the three reform models, the influence of accountability policy seemed to be most salient for teachers in Core Knowledge schools and one school relatively new to the International Baccalaureate model. These teachers described how science had been “placed on the back-burner” because it is not considered a “high stakes” subject with regard to standardized tests. In addition to describing how most of the instructional time within the school day was devoted to content that would appear on standardized tests, teachers noted that the allocation of time for science across the school year is uneven with more time being devoted at the beginning of the year before preparation for testing intensifies and at the end of the year once standardized tests are completed. Although teachers in Direct Instruction schools likely experience the same pressures of accountability policy and testing, it was the reform model and not these external policies that teachers cited as limiting time for science education. Teachers in the school that has fully implemented the International Baccalaureate model did not implicate either the policy environment or the reform model as limiting time for science. As noted above, to the extent that teachers at this school reported limited time for science, they referred primarily to instructional considerations, such as the time-consuming nature of science learning and an over-crowded science curriculum. Although teachers at this school did not express concern about standardized testing and accountability policy, they did discuss recent developments in science education reform, such as the adoption of new state and national standards.

Integrating Science with Other Subject Areas. Another common theme across reform models was the integration of science with other subject areas. Although teachers generally advocated integration as a key strategy for maximizing time available for science, there were clear differences in the degree and quality of integration supported by each reform model. Although the Direct Instruction model makes a nod to integrating science and other subject areas by including some science content in upper grades text, the model does not allow teachers to meaningfully integrate standards in various subject areas. Specifically, teachers in Direct Instruction schools expressed that the model did not allow time or support for the implementation of interdisciplinary units they had developed in the past. Teachers also complained that, to the degree that Direct

Instruction lessons incorporate science content, this integration was largely superficial, did not align with the State Science Standards they were required to teach, and didn't provide students with opportunities to engage in inquiry activities or develop conceptual understanding of science content. Teachers in Core Knowledge schools described integration as a common time-saving strategy. Core Knowledge teachers and documents describing the Core Knowledge Sequence indicate that, while the reform model may permit the creation of interdisciplinary lessons and units, integration is not an explicit feature of the model and therefore depends on individual teachers' approach to instruction. In contrast to the Direct Instruction and Core Knowledge models, the International Baccalaureate model explicitly values and supports interdisciplinary learning. Although there were clear differences in teachers' experience implementing interdisciplinary units between the two International Baccalaureate schools that participated in the study, teacher perspectives and documents describing the International Baccalaureate program clearly highlight interdisciplinary learning as a central feature of the model. In summary, the integration of science and mathematics, social studies, and language arts was prevented, in the case of Direct Instruction, permitted in the case of Core Knowledge, and clearly promoted by the International Baccalaureate model.

Research Question 3: Personal Agency Beliefs

This section describes personal agency beliefs prevalent among teachers implementing each comprehensive school reform model. For the purpose of this study, data were analyzed both in terms of teachers' overall context and capability beliefs and in terms of the more specific formulation provided by Ford's taxonomy. Specifically, the following three types of codes were applied to teachers' capability and context belief statements: 1) category codes indicating high, moderate, and/or low capability beliefs or positive, neutral, or negative context beliefs, 2) thematic codes describing the content of teachers' context and capability beliefs, and 3) taxonomy codes reflecting Ford's ten personal agency belief patterns. The application of these three types of codes is described below.

Category Codes

In order to capture variations in capability and context beliefs across reform models, teachers' statements related to capability or their school context were coded categorically as reflecting high, moderate, or low capability beliefs and positive, neutral, or negative context beliefs. Because individual teachers may have reported inconsistent context or capability beliefs (e.g. Identifying both positive and negative aspects of their school context), codes were applied to specific statements rather than at the teacher level.

Thematic Codes

Although the frequency with which teachers' comments reflected high, moderate, and low capability beliefs and positive, neutral, or negative context beliefs gives a general sense of the capability and context beliefs among the study participants, examining the content of teachers' statements revealed several predominant themes related to teachers' capability and context beliefs. Sequential analysis (Miles & Huberman, 1994) was employed in order to identify emergent themes and patterns related to capability and context beliefs. For capability beliefs, the resulting themes varied by reform model, and are identified in the relevant sections for each reform model. For context beliefs, across reform models, the data reflected three general thematic categories: 1) school climate, 2) the availability of resources, and 3) teacher and administrator support. Data related to each of these themes is reported by reform model in the subsequent analysis.

Taxonomy Codes

Recall that Ford's taxonomy of personal agency beliefs outlines ten possible patterns based on the interaction of teachers' capability and context beliefs. In previous studies, total scores on quantitative measures of capability and context beliefs (e.g. The STEBI and CBATS) have been used to apply Fords' framework and profile teachers' personal agency belief patterns. For example, a teacher with a high score on both the capability and context belief measures would be categorized as having a "Robust" personal agency belief pattern. Figure 1 presents a matrix illustrating the various personal agency belief patterns within Ford's framework and Table 9 provides brief definitions of the 10 personal agency belief patterns. Given that personal agency belief patterns are, according to Ford (1992), best understood as "thoughts about personal and environmental resources that may vary across situations and change over time in significant ways" (p. 137), the goal of this analysis is not to label participants with an indelible personal agency belief pattern. Indeed, Ford cautions against adopting a strict, trait-like interpretation of personal agency belief patterns. Rather, the personal agency beliefs articulated by teachers participating in this study are taken to reflect their beliefs about their science teaching capability and the supportiveness of their school environments within the particular timeframe and context of this study.

Regarding this last coding category, a teacher was classified as exhibiting one of Ford's ten personal agency belief patterns only in instances where they provided comments regarding both their capability as science teachers and their school context, or in cases where their statements clearly correspond to Ford's descriptions of his ten personal agency belief patterns. Additionally, because personal agency beliefs are, by definition, personal, teacher comments offered within jointly constructed focus group discussions were interpreted with caution. Only instances when teachers specifically spoke of their individual capability, rather than the overall capabilities of the school's teaching staff, were considered evidence of that teacher's capability beliefs. Similarly, only individual teacher statements about school context or explicit agreement with statements made by others were taken as evidence of context beliefs.

Personal Agency Beliefs in Direct Instruction Schools

This section summarizes the personal agency beliefs reported by teachers in Direct Instruction schools. Following the finding pertaining to teachers' capability and context beliefs, the specific personal agency belief patterns evidenced by teachers in Direct Instruction schools are described.

Capability beliefs. With a few exceptions, Direct Instruction teachers tended to provide a positive assessment of their science teaching ability. Table 10 presents the frequency with which teachers' statements regarding their capability were coded as high, moderate, or low. Examining these frequencies, we see that a the majority of statements made by the Direct Instruction teachers participating in this study were coded as exemplifying moderate or high capability beliefs. That is, when teachers commented on their capability to teach science, they tended to offer a positive assessment of their ability to teach science. For Direct Instruction teachers, the themes of student test performance and content knowledge mastery were apparent in the qualitative data.

Additionally, I examined the context of teachers' statements regarding capability and, specifically, the attributions teachers made regarding the source of their capability beliefs.

Student test performance. Teachers commonly discussed their efficacy as science teachers in terms of their students' performance on standardized tests. Among the teachers who participated in school focus groups and interviews, there were several who seemed to gauge their efficacy as science teachers according to how well their students performed on the CRCT in Science. One teacher remarked that "science is where I do my best teaching" and when asked to elaborate on how she knew that science was where her teaching was best, she references her student's performance on the CRCT stating, "it's because that's where my students have done the best. For three years in a row, all of my students have met or exceeded" (Interview, 4/21/11). Another teacher at the school commented on how she has become an instructional leader for science in her school noting, "if someone has a question about what materials to use to prepare students to really do well on the CRCT, I'm usually the one they come to" (Interview, 4/21/11). Here we see that teachers' assessments of their science teaching efficacy may be tied specifically to their students' performance on the CRCT and their ability to prepare their students or help other teachers prepare students for the test. Likewise, teachers who expressed moderate or low capability beliefs often based their assessment on their students' moderate or poor performance on the CRCT. For instance, when asked to describe her approach to science teaching, one survey respondent relates her low capability beliefs stating, "I'm no expert and I don't think I can be. My scores in Science have been low and I'm not sure how to bring them up since science isn't really my subject" (Interview 4/6/11). Variations on this comment were common among teachers expressing low capability beliefs. Similarly, in one focus group discussion two teachers express moderate capability beliefs in relation to their science test goals (3/9/11):

> Teacher 1: I know I'm not that great, but I'm getting better at teaching science…at least I think. I feel like my kids are more prepared this year, but it still won't be our best subject on the CRCT or even close really.
>
> Teacher 2: Well yeah, there are those veterans who seem to really know how to get their kids to do well, right, you know who I mean, but you can't always compare yourself to them, you can't just compare scores like that - I'm still figuring out what to do but I feel okay about where I am.

As teachers discussed their science teaching practices, many mentioned attributes that, in their mind, characterized excellent science teaching; however, the definition of "expertise" employed by many Direct Instruction teachers did not align with the sort of expertise called for by recent science education reform. For instance, when asked to elaborate on what made an elementary teacher an "expert" at teaching science, the two teachers above, in conversation with a third colleague, relate expertise to student achievement on standardized tests and the ability to cover all of the State Science standards in a given school year (3/31/11):

> Teacher 1: Well, it's really about the kids and how well they do. You know who the teachers are who have high science scores, so you've got to think they know what they are doing. That's who I'd want to observe, you know if I need help with practices to make sure they are ready to do well.

Teacher 2: Absolutely…and I'd add that the best teachers know how to plan, how to get everything in. That's where I guess I'm a bit short, like, we do pretty good on the standards we get to, mostly anyway, but the others not so much.

Teacher 3: Ok. Well, I kind of agree but I sort of think there's more to it. Yeah, the best teachers have good scores and they probably get through everything, but it not just that, right. That's too easy. It's also *how* they teach it, the kinds of strategies and things they use.

Asked to elaborate on what kinds of strategies they would expect to see in the best science teachers' classrooms, this dissenting teacher joked "well, if I knew that I would be a great science teacher" and went on to list a variety of approaches and techniques - "they might read from the book some days, do an experiment, projects, formative assessments all the time, differentiating for learning styles" and emphasized that the best teachers "change it up for what kids need, so they're ready in April." Interestingly, as evidenced by this teacher's ideal of having students "ready in April", this teacher sees even the most effective science teachers as having the goal of test readiness rather than enduring conceptual understanding.

Content knowledge mastery. In discussing their science teaching capability, Direct Instruction teachers' often referred to their level of content knowledge mastery. In response to the open-ended survey question asking teachers to comment on the science teaching advice they would provide a new teacher at their school several teachers drew a direct connection between mastery of science content and the ability to teach science effectively. For example, one teacher framed her moderate capability beliefs in terms of content knowledge stating that "in order to teach it, you have to know it. I wouldn't say I am at the top in teaching science, but when I take time to go back and really get into the topics we're teaching, I do better…so that's the advice I'd give someone new" (Interview, 4/21/11). Likewise, teachers whose statements portrayed relatively low capability beliefs often referred to a lack of content knowledge mastery. One interview participant attributed her lack of confidence teaching science to a lack of content knowledge noting (4/21/11):

> I'm no scientist. I wasn't a major or anything. You'd think because it's elementary it would be easy, but honestly some of these standards are real tough. I've never felt confident teaching science just 'cuz I don't know enough to do it as well as I should.

Teachers' comments on the degree to which their content knowledge was sufficient to teach science effectively also highlighted the extent to which teachers viewed science learning as a process of acquiring facts and amassing knowledge related to science topics rather than developing coherent conceptual understanding. Teachers in both schools commented on how they had "forgotten" or "lost" much of the science content they learned in school. In one focus group discussion, teachers discussed how much science content they forget from year to year and their process for "boning up" on science in order to teach students (3/31/11):

> Teacher 1: Yeah. There's a lot you have to know and I'll tell you, I'll admit that sometimes I forget from this year to the next one.
>
> Teacher 2: uh. So true. Like last week we were doing the plant parts and I'm like, really, I should remember this. I feel silly taking the 1st grade textbook home to study, but that's what you have to do if you don't know it.

Teacher 3: At least you do it and now your kids know the parts of a plant, that's good.

Thus, according to many of the Direct Instruction teachers who participated in this study, the ability to teach science effectively is in large part a function of science content mastery. Although teachers tended to speak generally about the degree to which they understood science or considered themselves a "science person", teachers specific comments also suggested a belief that achieving content knowledge mastery was a matter of learning and remembering discrete facts related to science topics rather than developing coherent conceptual understanding.

Teachers' capability attributions. When teachers offered statements regarding their capability as science teachers, they often contextualized these statements by attributing their science teaching capability to a specific source. Comparing the attributions made by teachers expressing high, moderate, and low capability beliefs suggests a possible relationship between teachers beliefs about their science teaching ability and implementation of the Direct Instruction reform model. Direct Instruction teachers expressing positive capability beliefs most often attributed their science teaching ability to their formal education, professional development experiences outside of the school setting (i.e. Workshops at conferences), and/or their personal interest and experience with science. For example, one teacher noted that "what I know about teaching science comes mainly from my father. He was a science prof at Tech and got me in the lab young, so I've always loved science and I try to pass that to my students" (Interview, 4/6/11). One survey respondent credits her experience teaching at another school and her participation in district professional development and science teaching organizations stating, “The last school I taught at was big on sending us to GSTA, NSTA, all that, so I got to sit in on workshops and hang out with other teachers, I think that’s been the biggest thing for me. Not sure if our school would do it now, but I’d tell a new teacher to go to conferences”. In contrast, twelve of the fourteen Direct Instruction teachers who expressed negative capability beliefs implicated the Direct Instruction model in some way. Most commonly, teachers expressed that they would be better science teachers if their school did not have the Direct Instruction reform model or that they were more effective science teachers before the school adopted the reform model. This perspective is evident in the following focus group exchange (Focus Group 3/9/11):

> Teacher 1: It used to be different, with Modern Red.
>
> JG: Tell me about Modern Red.
>
> Teacher 1: It’s what we had before D.I. It was more like thematic units.
>
> Teacher 2: Yeah. I felt like.. Well, like a good science teacher then, like I could do it the right way. Now I kind of suck. (Laughs)
>
> Teacher 3: Well, yeah. I mean I don’t think it’s your fault, we don’t get to do science, so how would we be so good at it. I guess I could be, like I think I have it in me but I’m not because we don’t focus on it day to day.
>
> Teacher 1: Like with Modern Red you could try new things out, it was more flexible not like a script like DI and there was some time, but now I don’t really know how good I am at it because we don’t do it much so I guess if its not like riding a bike, if you gotta keep working to teach science the best you can..

Teacher 2: no, not a bike at all. I'm not nearly as good, as good as I used to be - really, I mean it takes practice, especially if science isn't your main thing, so now I'm not confident at all.

Similarly, teachers spoke of a lack of motivation and accountability for effective science teaching stemming from the implementation of the Direct Instruction model. One focus group discussion regarding professional development for science teaching highlighted teachers' awareness that their school leaders were more interested in evaluating the fidelity of their implementation of the D.I. reform model than of the district's science initiative. Teachers at this school stated that while they attended the district-wide professional development conference for the initiative, they did so with the expectation that they would not be able to any of the strategies that they learned. One teacher describes her school's expectations for the conference, "Yeah, we were there, and some of the activities, all the inquiry and the essential labs, they looked great, but we knew we couldn't do them" (3/9/11). Asked to elaborate on why she believed teachers would be unable to implement the initiative activities, the teacher responded "well, I mean I might be able, I think I could maybe pull it off, it's not really that - but there's just no way we could do it with DI 'cuz that's what they care about most, if we do DI right, not science."

This finding that many teachers with low capability beliefs attributed their inability to teach science effectively to the Direct Instruction reform model provides compelling rationale for examining teachers' beliefs about their science teaching context and applying Ford's taxonomy of personal agency belief patterns to examine the interaction between capability and context beliefs. The sections below describe the context beliefs held by Direct Instruction teachers participating in this study and the personal agency belief patterns that emerged from the qualitative data analysis.

Context beliefs. With few exceptions, the Direct Instruction teachers who participated in this study expressed clear negative beliefs about the degree to which their school context supports effective science teaching. Of the 46 statements related to school context made by Direct Instruction teachers in surveys, interviews, and focus groups, only 4 suggested positive context beliefs. Two of these statements were short, general assessments (e.g."we do pretty well with science at my school") provided by survey participants from Direct Instruction schools that did not participate in the interview or focus group portions of the study. The remaining positive statements were offered by teachers within a focus group conversation and related to the availability of materials resources for science teaching. As positive statements regarding the D.I. school context were relatively rare in this data set, this analysis focuses on exploring teachers' negative views about their school context. Three themes emerged form the analysis of statements related to teachers' context beliefs: school climate, the availability of resources, and support from colleagues and administrators.

School Climate. As evident in one teachers' attribution of low capability to her perception that hers was "a D.I. school not a science school", Direct Instruction teachers participating in this study described a school climate that, in their estimation, was not conducive to effective science teaching. Asked to describe their school's approach to science education, one school focus group engaged in an extended discussion of school climate that included the following exchange (3/9/11):

Teacher 1: It's more than just having stuff - kits and even PD - it's a school thing, a school culture thing.

JG: Can you tell me more about what you mean by "school culture"? What does that look like here?

Teacher 1: Well, I can tell you it doesn't look like science. (Laughing).

Teacher 2: It's like, what we value, what everyone is committed to - not just the stupid mission statement, but what everyone is on board to do.

Teacher 3: Ok. Right. So here's the thing - we aren't one of those touchy feely schools here. We can't be.

JG: What do you mean by "touchy feely"?

Teacher 3: Well, one of those schools where its all about letting the kids (quote unquote) *explore their world*, where the kids decide what to do and we're all so concerned about them getting their freedom to like I said explore…There's really not a lot of that .

Teacher 4: Yeah - it's a tight ship, kind of like a machine is how they want it.

Teacher 2: Orderly, that's the best word. And I just don't see anyone going for it if we wanted to do some big inquiry thing where kids are loud and materials are all over the room and they might be learning something really but if Dr. ______ (Principal) comes in he'd think it was a crazy mess. He says do the inquiry but I know he'd freak.

JG: Which way would you like it to be? How would you change the culture if you could?

Teacher 3: Well, I'm not into the touchy feely, but with science I guess it would be good if we were doing the essential labs I know they let kids experiment more and..

Teacher 2: and that's good for them - I'd say in the middle - still orderly in the halls and kids listen and mind, but they also get do more hands-on lessons where its just a little more about students.

Teacher 1: I'd just want everyone to get with it and really get into science, think its important to teach - if that happened then other, like how we do the labs and all, that stuff might start to be different if the culture changes.

Thus, teachers at this school perceive a school culture that, in its emphasis on maintaining order and encouraging teacher led instruction, is inconsistent with a more flexible, exploratory climate that would support science teaching and learning. This prioritization of maintaining order over free exploration was confirmed by an interview participant from the same school who describes her school as (4/6/11):

> a good school in some ways - the kids behave, it's efficient and we get a lot of other stuff done. But, it's not good for science, what I mean is there's no push to do the labs and projects and things I know go on at other schools, its just not how our school runs.

Although teachers at the second Direct Instruction school also described their school culture as being inconsistent with the goals of the science education initiative, their discussion focused more on the school climate reinforcing the prioritization of mathematics and reading over other subject areas. Within this discussion, one teacher shared her belief that "if my kids can't read, they can't do science so the reading has to come first", a statement with which a number of other focus group participants agreed (Focus Group, 3/31/11). Asked to describe the school's approach to science education, one teacher explained that there "isn't really a school wide thing for science … we focus a lot on the reading and math 'cuz of CRCT and 3rd and 5th we do more science, but here its not like science is at the top of the list for what the school as a whole is all about" (Focus Group, 3/31/11).

The Availability of Resources. Although Direct Instruction teachers generally agreed that their school provided the basic material resources required for science teaching, teachers at both Direct Instruction schools contended that investment in science teaching resources was not a priority at their school. For instance, teachers noted that they had access to science kits that could be used to carryout the Essential Labs required by the district's science initiative, but that once the materials for these labs were used, they were not replenished. Similarly, one interview participant reported that she plans simple science lessons that do not require materials provided by the school because she isn't confident that the supplies she needs will always be available.

In addition to inconsistency in the availability of material resources, teachers at Direct Instruction schools emphasized time as an instructional resource that is at once highly valued and extremely scarce within their school contexts. Because Research Question #3 explores the issue of time allocation in depth, here I will briefly highlight findings that specifically connect teachers' context beliefs with their perspectives on the availability of time for science.

Direct Instruction teachers were nearly unanimous in their view that time for science instruction was insufficient at their schools. Of the 22 teachers who responded to open-ended survey questions, 16 mentioned that there was a lack of time for science in their schools or classrooms. That the survey did not specifically ask teachers to comment on the availability of time but teachers felt compelled to mention it as a factor influencing their science teaching experience further underscores the extent to which teachers view time as a valuable but scarce instructional resource. Similarly, within focus group discussions and interviews, when asked to describe their schools approach to science or typical science lessons taking place in their classrooms, nearly all of the Direct Instruction teachers spontaneously discuss the scarcity of time for science. For example, in one school, teachers explicitly outlined the school schedule, noting that science was “sometimes lumped in with specials” (i.e. Art, Music, Computer Lab) or “stuck at the end of the day” (Focus Group 3/9/11). One teacher within this group then points out “so, that should tell you how important the school thinks science is” and another makes the joke “yeah, we literally won’t give it the time of day.” At this school, teachers plainly saw time as one, if not the primary, school context factor limiting their ability to teach science effectively. One teacher makes clear the connection between time allocation and her negative context beliefs positing, “it’s really all about the time. If we had time, if they carved it out of the schedule, I think we could do a lot with science. Since there’s no time, we don’t do much at all.”

Teachers were also quick to point out that the time allocated to science in the official school schedule was unrealistic and overestimates the amount of time they actually devote to science in their classrooms. One teacher takes issue with this practice, suggesting that “we should stop kidding ourselves and get real - we know they don’t *really* care if we get to it, so why even put it on the schedule?” Another teacher responds affirmatively and adds that "we can fake it but that doesn't help the kids so if they want us to do it right, they have to give us the time." This conversation continued with teachers drawing a connection to the school's emphasis on standardized testing and accountability. At this point one teacher wonders aloud whether "once science matters for AYP, I think we might have more." Teachers were divided in their predictions, with some being optimistic that greater accountability would lead to greater time for science and others arguing that instructional time would remain focused on reading and mathematics.

In addition to attributing the scarcity of time to the pressures of standardized testing, several teachers specifically discussed the relationship between their school's implementation of the Direct Instruction reform model and limited time for science. Indeed, in both focus group discussions and three out of four interviews, teachers directly implicated the reform model as limiting time for science.

Teacher and Administrator Support. As intimated within teachers' discussions of school culture and science teaching, a lack of leadership for science instruction was cited as a major obstacle to effective science teaching. Although two teachers pointed to instances in which school leaders made efforts to support science instruction (e.g. Securing textbooks and materials), overall, teachers described a lack of leadership for science in their schools. Specifically, teachers spoke of school administrators who set low expectations for science teaching and learning and failed to support teacher engagement in science professional development.

Teachers' negative context beliefs were embodied in a number of examples of schools failing to instill high expectations for science teaching and learning. One of the primary mechanisms by which this occurred was through what one teacher characterized as school administrators' "preoccupation with the test" (Interview, 4/6/11). Teachers reported that although substantial time is devoted to analyzing student achievement results on mathematics, reading, and language arts tests in order to improve instruction, their principals and grade level chairs do not ask them to do the same for student achievement on standardized tests in science. This claim was substantiated by bulletin boards noted during observation visits, which under the heading "We are Data Driven" displayed bar graphs illustrating grade level standardized test results in mathematics, reading, and language arts, but not science. Several teachers shared that in faculty meetings and individual conversations their school principals and teacher serving as department chairs explicitly directed them to focus instructional time on mathematics and language arts even if it meant taking time away from science and social studies.

Another way that school leaders typically failed to support Direct Instruction teachers' was through denying opportunities or devaluing teachers' interest in science professional development. One teacher shared that when she asked her principal if she could have a letter of recommendation for a summer program she was applying for within a national science teacher organization, she was told that he was too busy to write the letter and asked to justify her desire to attend the program: "He just said no, he wouldn't be able to…and then he asked 'what made you want to apply for that anyway'? "(Interview, 4/21/11). Two fifth grade teachers at the other Direct Instruction school shared that their grade level had hoped to use their common planning time to create science mini-lessons to supplement concepts mentioned in their students' reading texts. The teachers noted that they expected their school's instructional coach to be impressed by their effort and perhaps suggest that other grade levels do the same, but instead they were told that they should devote their planning time to sharing test preparation strategies and practicing the scripted D.I. Lessons.

Personal Agency Belief Patterns. The frequency of each personal agency belief pattern by reform model and data source is presented in Table 11. Among the Direct Instruction teachers whose personal agency belief patterns could be classified, the most common patterns were the Antagonistic (n=6), Discouraged (n=6), and Accepting (n=5) patterns. Evidence for the personal agency belief patterns most commonly demonstrated by Direct Instruction teachers is presented below.

Among the most common personal agency belief classifications for Direct Instruction teachers were the Antagonistic and Accepting patterns, which are both indicative of negative context beliefs coupled with strong beliefs on one's capability. According to Ford, the Antagonistic and Accepting patterns are both characterized by "a general sense of self-adequacy combined with a significant degree of distrust or hostility toward the environment" and a tendency to "blame some aspect of the context rather than themselves for problems and failures" (p. 135). Ford argues that this enables individuals to maintain some motivation in spite of their unresponsive context, either by triggering heightened arousal, in the case of the Antagonistic pattern (e.g. "I'm not quitting until I make this work!") or by initiating coping processes that may minimize the effects of the problematic context (e.g., "All I can do is accept it and not try to think about it").

Consistent with Ford's definition, teachers exhibiting the Antagonistic pattern tended to express frustration about their school's lack of commitment to science education while at the same time emphasizing their ability to teach science effectively. When asked to describe her school's approach to science education, one survey respondent stated simply "what approach? Science is not a priority at this school". However, when asked to describe a typical lesson in her classroom, the same teacher follows her description of an inquiry activity with the statement:

> I do everything I can to make sure they get it…Science used to be my least favorite, I wasn't very creative but I've come a long way and now we do a lot of things in my class that I don't see happening across the school.

Interestingly, several teachers with the Antagonistic pattern described teaching science as a sort of subversive act requiring them to transgress the rules and expectations within their school context in order to pursue their science teaching goals. For example, one interview participant shared what she called her "sneak and teach" strategy, which involved finding ways to alter or omit elements of the typical Direct Instruction lesson sequence in order to create time for science and social studies (4/6/11):

> So here's what I do, don't tell on me, K? (laughs). So it's real repetitive, you know - the same sounds and words for days and I know my kids can read them. They don't need to do it 42 times. So I skip a lot of lessons - on the report at the end of the week it'll say we did 14 or 15 but we did like 8 and the kids still killed it on the fluency test. That buys us about 20 minutes a day that we can get some science in….I'm not afraid to do that kind of thing if I know what's best for my kids.

Teachers demonstrating the Accepting pattern also expressed frustration with their school context; however, instead of working actively against the unsupportive context, these teachers tended to express passive acceptance of their school context. The Accepting pattern was evident in a discussion of the school's adoption of the Direct Instruction reform model among three teachers in one school focus group (3/31/11):

> Teacher 1: I wasn't even here when they voted to bring in D.I., but I just have to go with it…even though I know how to do more.
>
> Teacher 2: Yeah. I guess it's not fair really, because its such a big program and all… you should have a say what you teach everyday.
>
> Teacher 1: Right, but whatever, I try not to worry about it. It's beyond my control, you know, so there's just… I mean sometimes I'd like to do more and I know I can but..
>
> Teacher 3: But you do the best with what you got. I'm not sayin' I'm happy about it, not at all, but no good fussing - just teach the science the way you know how…
>
> Teacher 2: When you can, that's what I do. Just teach like I've always done and it'll be fine. It's just not worth it to worry if you can't do anything.

Here teachers acknowledge their ability to teach science while also describing how their school context is limiting their science teaching. In particular, this discussion highlights the implications of the school's initial adoption of the Direct Instruction model for teachers. Once the school faculty votes to adopt the model, teachers, including those who join the staff after the initial vote, are responsible for implementation. Teachers at this school perceived the adoption of the model as a permanent decision. One teacher assumed personal responsibility for the adoption stating "we made our bed and now we have to sleep in it" (Focus Group 3/31/11). Thus, one reason that teachers may feel they have no choice but to tolerate an unsupportive school context is that, by buying into the Direct Instruction model, they may have been complicit in creating it.

The Discouraged personal agency belief pattern was also common among Direct Instruction teachers. Like the Accepting and Antagonistic patterns, teachers exhibiting the Discouraged pattern tend to have negative beliefs about their school context. However, unlike the relatively strong capability beliefs indicative of the previous two patterns, Discouraged teachers' negative context beliefs were coupled with more moderate or variable capability beliefs. Still, Ford hypothesizes that Discouraged individuals are "less likely to focus on their personal deficiencies than on the impossibilities of making progress in the current context" (p.136). Direct Instruction teachers exhibiting the Discouraged pattern intimated that while their science teaching ability was somewhat limited, they expected that they could be much better teachers if their school were more supportive. For instance, one teacher states (4/6/11):

> I'm not saying I'm great when science is involved, like I don't exactly know how to do labs well and a lot of the lessons I have taught I'm not exactly well, proud of them, but it's really the fact that there's not a big push for it here, I mean there's not really a reason to get into it and a lot of pressure for other things so why do it?

Unfortunately, four teachers' responses were indicative of the Hopeless personal agency belief pattern, which is deemed by Ford the "most motivationally debilitating pattern". Characterized by negative context beliefs and weak capability beliefs, teachers exhibiting the Hopeless pattern could be described as having abandoned their science learning goals, and may embody Ford's statement that, "good outcomes are seen as impossible and bad outcomes are seen as inevitable" (p. 137). One survey participant conveys this pessimistic view of capability and context beliefs stating, "I feel like I basically gave up on teaching science, it's just not my area and we don't have any time for it." In one focus group session, two teachers discussed their hopelessness regarding their science teaching (3/9/11):

> Teacher 1: It's just not going to happen at this school. I'd like to be a good science teacher, but there's no support at all so I'm not good and I don't think it will be different unless I go somewhere else.
>
> Teacher 2: I'm thinking maybe I'll try middle school, teach ELA or social studies so I don't have to do science.
>
> Teacher 1: I've thought about that, but then there was the Math-Science program so I thought maybe now I'd get some help, but nope.

Relatively few Direct Instruction teachers could be classified as exemplifying the Tenacious (n=3), Vulnerable (n=2), Robust (n=2), Modest (n=1), and Fragile (n=1) personal agency belief patterns. Consistent with the analysis of teachers' capability and context belief statements, most frequently, Direct Instruction teachers' personal agency beliefs tended to align with patterns characterized by moderate or high capability beliefs and negative context beliefs.

Personal Agency Beliefs in Core Knowledge Schools

This section summarizes the personal agency beliefs reported by teachers in Core Knowledge schools. Following findings pertaining to teachers' capability and context beliefs, the specific personal agency belief patterns evidenced by teachers in Core Knowledge schools are described.

Capability beliefs. With few exceptions, the Core Knowledge teachers who participated in this study evince moderate to high capability beliefs. Table 10 presents the frequency with which teachers' statements regarding their capability were coded as high, moderate, or low. Examining these frequencies, we see that a the majority of statements made by the Core Knowledge teachers participating in this study were coded as exemplifying moderate or high capability beliefs. Although the frequency with which teachers comments reflected high, moderate, and low capability beliefs gives a general sense of teachers' capability, as with the Direct Instruction teachers, examining the content and context of teachers' statements more closely revealed several themes related to teachers' capability beliefs. For Core Knowledge teachers, the themes of curriculum coverage, content knowledge mastery, and inquiry oriented teaching were apparent in the qualitative data. Again, I also examined the context of teachers' statements regarding capability and, specifically, the attributions teachers made regarding the sources of their capability.

Curriculum Coverage. Teachers from Core Knowledge schools commonly framed their assessment of their science teaching in terms of their ability to cover the designated Core Knowledge sequence and State Science Standards over the course of the school year. Within both school focus groups, teachers spoke of the challenge of working through all the Core Knowledge science curricula within the time allotted for science instruction and, to a certain degree, gauged their capability as science teachers by the amount of content they were able to deliver. The few Core Knowledge teachers who saw themselves as novice or ineffective science teachers each cited an inability to equip their students with the skills outlined by the Core Knowledge sequence and teachers who saw themselves as more effective often touted their ability to cover the sequence in its entirety. This perspective is evident in one teachers' reflections on her growth as a science teacher (Focus Group, 2/23/11):

> In the beginning, the first year, I mean, I guess I would say I really struggled. We didn't get to most of the 2^{nd} grade skills, maybe about half just 'cuz of time and I hadn't learned to plan so well, so I don't think my students went to 3^{rd} grade knowing what they should… Now that I've got it, figured out how I can be more efficient and get to more, science is one of my best areas now.

As alluded to above, along with emphasizing the importance of covering all of the content within the Core Knowledge sequence, teachers highlighted instructional planning and time management as criteria for excellent science teaching. In one school focus group, teachers shared their school's process for drafting a long-term instructional plan aligning the Core Knowledge sequence with the State Science Standards (3/10/11):

> Teacher 1: There's just not any time to waste, so you've got to be…what's the best…well, purposeful about how you use it, like how we did the planning last summer.
>
> Teacher 2: Yeah. We had these new standards we were working with, well pretty new, and we saw how they sort of fit with Core but not all the way so we had to align everything and plot it out on a calendar.
>
> Teacher 3: Every grade level did this. Anything that was in the standards but not in Core, we had to find a way to fit them in or integrate them somewhere.

> Teacher 1: Not an easy task at all, but we did it. Since we have this plan, we know everything is laid out in advance and we make some revisions as we go, but not too many. So since we did this, I think the science teaching is a lot better across the board. Everyone seems to be really making more progress this year. At least I feel like I'm doing better.

Thus, it appears that Core Knowledge teachers participating in this study had internalized the program's requirement, as stated in the Core Knowledge sequence, that "teachers make a commitment to teach all the topics in the Sequence at the assigned grade levels" (Core Knowledge Foundation, 2010, p.ix). For these teachers, efficacy depends not merely on *how well* one teaches science but also on *how much* science one manages to teach.

Content Knowledge Mastery. In discussing their science teaching capability, Core Knowledge teachers were adamant that their ability to teach science well depends, in large part, on their own mastery of the science content. At one school, in particular, teachers described how their instructional coach actively encourages teachers to deepen content knowledge by providing additional resources and occasional professional development opportunities. For example, one teacher shared that the instructional coach routinely shares articles from popular science magazines that relate to the content in the Core Sequence (4/7/11):

> At first I was like 'what's this? Scientific American? My kids are in 2nd grade - they can't read this', but then I realized it was for me. She wanted to make sure I was keeping up with the topics in science, beyond just what's in the textbook.

This notion of going "beyond the textbook" to master science content recurred throughout school focus group conversations and interviews at both schools. Teachers in one focus group unanimously agreed with one teacher's statement that it isn't enough to read ahead in the students' text book; however, teachers varied in the degree to which they actually consulted additional material to advance their science content knowledge. For instance, One 5th grade teacher admits "yeah, that's the goal of course…to really read up on the topics, but if I'm honest, in science, I'm usually just a step ahead of the kids" (Focus Group, 2/23/11). One of the few Core Knowledge teachers to plainly evince low capability beliefs attributed her science teaching difficulties primarily to a lack of content knowledge in science, stating (Interview, 4/7/11):

> So my problem I think is that I don't have the experience with science… I didn't major in it or work in a lab and I don't remember hardly anything from my science classes, so I sort of feel like I'm starting where the kids are, so I guess not that surprising that science isn't my best subject as a teacher.

Inquiry Oriented Teaching. In addition to curriculum coverage and content knowledge mastery, inquiry oriented teaching emerged as another indicator of science teaching capability. Generally, teachers referenced their ability to effectively guide student inquiry as an indicator of effective science teaching. Teachers who spoke highly of themselves as science teachers often referenced their ability to engage students in inquiry activities, whereas teachers who had doubts about their science teaching ability tended to report that they less successful when it came to implementing inquiry oriented activities. For instance, one teacher gauges her moderate capability in terms of her ability to lead inquiry activities, stating (Focus Group, 2/23/11):

> I'm ok with science, still getting it. I'm fine when we stick to the book, but those Essential Labs, some haven't gone so well - I can prepare everything and manage the lab ok, but I'm not always sure they really get it.

Similarly, many teachers described their growth as science teachers as a trajectory moving from more traditional science teaching to what they describe as a more inquiry based approach. For instance, one veteran teacher explained that until recently she was more of an "old school type" teacher and had "come along way when it comes to letting the kids explore and see and touch the science for themselves not just in the book" (Interview, 4/7/11). At the same time, it was common for teachers to equate the Core Knowledge model with more traditional approaches to science teaching, as evidenced by one teachers' complaint (Interview, 3/14/11):

> Core Knowledge doesn't get at what I think is really best, the best kind of science teaching…it's more about just what kids know - what they can tell you and remember - not really about how they think. So I could do cool things, way better that what I do now, but I'm pretty much stuck to just teaching the traditional way.

Although most of the Core Knowledge teachers participating in this study equated their vision of inquiry oriented teaching with effective teaching, there were several noteworthy exceptions. In three cases, teachers at once expressed high capability beliefs and either explicitly denied the importance of inquiry or credited their science teaching efficacy to their ability to implement practices antithetical to inquiry oriented science teaching. In an interview, one teacher described her efficacy in terms of the specific facts her students' mastered and how well they were able to retain these facts (3/14/11):

> Teacher: One important thing, something that I'm good at when I teach science, is that they have to see it a few times. We'll read it together, then they'll read and take notes, then they might tell it to someone for homework.
>
> JG: Can you give me an example?
>
> Teacher: Sure, so they learn the parts of the eye in my class. They read it, we read it, they do a homework sheet, it's on the wall. To this day, you find a 5th grader who was with me for 3rd and ask "what are the parts of the eye"? I guarantee they'll say cornea, iris, pupil, lens, retina.
>
> JG: Do you think they really understand it?
>
> Teacher: Well, yeah. They could tell you want each part is on a diagram.
>
> JG: and they really understand how the eye works?
>
> Teacher: Hmm. (Pause). Not all of them, some might have some idea what the parts do but we don't get into it that deep. I guess that's more advanced. I focus on making sure they know the basic facts straight so when they see it later and its time for them to learn more they'll be ready.

This example resonates with the account given by one teacher who defended her more traditional approach, stating "my students know the science just like they always have, you'd be surprised how much they absorb… If they know it, they know it" (3/14/11). Thus, as with the Direct Instruction teachers, the metric Core Knowledge teachers use to assess their own science teaching efficacy did not necessarily align with the vision of effective science teaching and inquiry called for by science education reform.

Teachers' capability attributions. A comparison of the attributions made by teachers expressing high, moderate, and low capability beliefs suggests a possible relationship between teachers beliefs about their science teaching ability and implementation of the Core Knowledge reform model. As explained above, teachers' who expressed high capability beliefs often cited their ability to adequately cover the curriculum, their own content knowledge mastery, and the degree to which they implement inquiry oriented teaching practices. Interestingly, teachers with varying degrees of capability implicated the Core Knowledge reform model in their ability to achieve each of these three indicators. At one school, teachers stated unequivocally that the amount of science content they were able to teach had increased substantially since the school adopted the Core Knowledge reform model. The majority of teachers at the second Core Knowledge school expressed an opposing view, insisting that the amount of science content included in the Core Knowledge sequence was unrealistic and limited their ability to adequately cover the State Science Standards. One interview participant from this second school drew a direct connection between her low- capability and the reform model, stating that "Core doesn't make it easy to teach science the right way, so no, I don't think I'm doing great things in science, really" (3/14/11). Thus, for certain teachers and school communities, the Core Knowledge model was seen as facilitating effective science teaching, as defined by teachers; however, other teachers highlighted ways in which the model limited their ability to realize their science teaching potential.

Although the Core Knowledge model may have been a factor for some teachers and schools, teachers were much more likely to attribute their efficacy as science teachers to factors originating beyond the school than they were to their school's adoption of the reform model. The majority of attributions expressed by teachers with low capability beliefs related to accountability and reform policies including national reform initiatives (e.g.: No Child Left Behind, Race to the Top), the State's standardized testing program, and district level policies (e.g. Merit pay, promotion, tenure, transfer policies). Most commonly, teachers discussed how such policies limited their ability to continually improve their science teaching practice. For instance, one teacher describes accountability as a disincentive for science teaching (Focus Group, 3/10/11):

> Even if I were great, which I'm not, but if I were good at teaching science, it wouldn't really matter, I don't really feel pushed to try new things 'cuz with NCLB and testing science isn't what's important.

Context beliefs. Beliefs about the degree to which their school context supports effective science varied widely among teachers from Core Knowledge schools. Of thirty six statements regarding school context made by Core Knowledge teachers, sixteen statements were positive, eleven statements were neutral, and eleven statements were negative. Consistent with the previous results regarding the allocation of time for science, there was a difference in teachers context beliefs between School A and School B, with a greater proportion of positive comments made by teachers at School A and the majority of negative comments made by teachers at School B. Three main themes emerged form the analysis of statements related to teachers' context beliefs: school climate, accountability policy (i.e. Standardized tests, AYP), and the allocation of resources. Given the between school differences noted above, the following summary discusses overall trends among Core Knowledge teachers as well as trends within each of the Core Knowledge schools that participated in this study.

School climate. School climate was a recurring topic in focus group conversations at both Core Knowledge schools and within teachers' responses to open ended survey questions. Teachers at School A debated the extent to which their school culture encouraged what one teacher referred to as "a science friendly atmosphere" (Focus Group, 2/23/11). While several teachers contended that they felt that science was as valued as other subjects at the school, others highlighted aspects of their school's climate that they perceived as limitations for science teaching. In particular, teachers at School A expressed concerns about a school climate that focuses on maintaining order over fostering exploration and curiosity. For instance, one teacher discussed how this "rigidity" manifested in her science lessons (2/23/11):

> So there are going to say we should do experiments, like the essential labs, but they don't want to see a mess, with kids doing ten different things and a lot of noise, really they want to see them working through it, through all the concepts and the labs without all that chaos.

Teachers from School B described a more positive climate for science education but maintained that the degree to which science teaching occurs is dependent on individual classroom teachers. At this school, in both interviews and the school focus group, teachers acknowledged that the school had paid more attention to science in recent years and attributed this increased attention in large part to the district's Math-Science Initiative. Teachers from this school recounted that the school's instructional coach had begun to facilitate additional professional development opportunities related to science, including a peer coaching model in which teachers were required to observe and provide feedback to other members of their grade level teams. Teachers noted that until the current school year they were required to observe lessons in mathematics and reading/language arts, but not science. One teacher describes the implication of adding science as a subject in which teachers could choose to observe and learn from one another stating, “doing that, adding science in this year, I think makes a difference…it’s showing and sending this message that maybe science is an important part of what we do here” (Focus Group, 3/10/11). Even with such changes, teachers at School B highlighted the variability in teachers’ commitment to science teaching across the school. One interview participant from this school estimates that “maybe 2/3 of the teachers really teach science at all… and then about half just stick to the sequence and don’t get into all the standards, and then about half who teach the standards do a real, I mean, really do a great job” (4/7/11). Whether or not this teacher’s estimate is accurate, it is clear that this teacher and several of her colleagues believe that theirs is a school where science, in many respects, is seen as optional.

Core Knowledge teachers also highlighted school climate in their responses to open-ended survey questions. Asked to describe their school’s approach to science education, teachers generally made statements about whether or not science was emphasized at their school. Occasionally, such statements were related to specific aspects of school climate. For instance, one teacher stated that “science is really big at my school, especially in recent years since we’ve tried to have a more child-centered, relaxed environment where kids get to explore.” Just as some teachers described how school climate promoted science, others highlighted aspects of their school climate that limited science education. One third grade teacher, for example, describes her school's approach to science education as "lacking…we don't do nearly as much as we should" also describes her school as "pretty regimented" and having "more of a serious approach where we focus on the basics and don't generally get a lot of time for kids to experiment beyond that."

In addition to their more general remarks on school climate and culture, Core Knowledge teachers highlighted accountability policy, and specifically standardized testing and pressures to meet AYP, as salient features of their school climate. Although the pressures of standardized testing tended to manifest differently at School A and School B, at both Core Knowledge schools where focus groups were held, teachers described how standardized testing had narrowed their school curriculum to focus primarily on "high-stakes" subjects (i.e. Subjects where standardized test scores are used to determine promotion/retention of students and school AYP). This curriculum narrowing appeared to be particularly acute at School A, where several teachers reported that they had been explicitly instructed to focus their instruction on tested subject areas. Teachers at this school also reported that time and attention devoted to science tended to be determined by the annual testing calendar, with more time for science available for science at the beginning and end of the school year when the school isn't "in test-prep mode" (Focus group 3/10/11).

Teachers at School B also emphasized standardized testing as a major factor limiting their ability to teach science effectively. One teacher at School B describes the effects of standardized testing on her science instruction

> it used to be about teaching for mastery, getting them to think critically whether in science or any other subject, but now with the tests being so…what's the word… (another teacher chimes in "ubiquitous")….yes, ubiquitous - whether we like it or not, these tests are important, they have consequences so we've definitely shifted more toward test prep and if science isn't on the test or if the science test doesn't count, what do you expect? (3/10/11)

Following this comment, teachers at School B engaged in a lively discussion about the ways in which the school is negotiating the tensions between science instruction and test preparation in other subjects. Within this conversation, it became evident that teachers at School B saw the pressures of accountability policy as originating beyond the school level with state and national policies (i.e. AYP, NCLB, Race to the Top). Unlike teachers at School A, who reported that leaders and other teachers at their school actively encouraged them to scale back or eliminate science instruction in order to focus on tested subjects, teachers at School B discussed ways in which their school leadership worked with them to acknowledge and negotiate the pressures of accountability policy. Two teachers discuss how teachers and leadership work together within this context (3/10/11):

> Teacher 1: it's not like anyone tells us 'don't teach science' - it's just part of the system, it's how things are and it's not just our school's fault…
>
> Teacher 2: Right. Mr. (Principal) and Ms. (Instructional Coach) are in it, I mean we're in it together… it's not like they invented the tests

Teacher 1: So I see how we can do more, but a lot of it is beyond the school's control - we can't just rebel and not do the tests - but I can see how they 'get it', they are tryin' to work with us to figure out how to get science back in.

Teachers at School B also noted that their school's successful track record on standardized tests worked in their favor when it came to reclaiming time and space in the school curriculum for science. One interview participant claimed that since their school had made AYP for several years in a row, the school wasn't "as nervous and high strung about the tests" (4/7/11). Elaborating on this change, she states that "now that we've kind of got it, that we don't have to spend every minute prepping for a test, we're starting to see that maybe science can be worked back in." Similarly, one focus group participant notes that "we're a pretty good school now, as far as testing, so if can just keep that up I think we'll have more freedom for science and social studies and such…that would be great" (3/10/11). These statements suggest that the pressures of standardized testing may be somewhat less intense for schools that have continually met their standardized testing goals. However, that teachers in a school that has excelled on standardized tests speak only tentatively of the possibility that "maybe science can be worked back in" illustrates the extent to which the pressures of accountability policy continue to impact science education.

The availability of resources. The allocation of resources for science education emerged as another important aspect of the school context at Core Knowledge schools. With the exception of two teachers at School A who claimed that certain material resources were unevenly allocated across grade levels, teachers tended to agree that the material resources needed to teach science were generally available. Specifically, teachers affirmed that they had access to textbooks, technology, and science kits to support their science instruction. One survey respondent describes the availability of science materials at her school, stating that "I have more stuff for teaching science than I ever thought I would - textbooks, games, kits, programs, specimens, you name it." This statement was echoed by one interview participant who stated simply, "I have everything I need - there's no lack of materials" (4/7/11).

The availability of material resources reported by Core Knowledge teachers contrasts with a clear lack of time and social resources, described by Knapp and Plecki as "residing in teachers' and learners' attitudes toward learning, science, and each other" (p. 1094). As detailed in research question 2, Core Knowledge teachers frequently cited the scarcity of time as a primary factor limiting their science instruction. Indeed, in discussing their school context, many teachers drew a direct contrast between the wealth of material resources at their school and the paucity of time required to actualize such resources. For instance, one teacher expresses her frustration, stating "yeah I've got the kits, all the books and even those sensors, so you are going to give me all that and then not give me time to use it?" (Focus Group, 3/10/11) Teachers also described how the availability of social resources, such as support from administration and other teachers, could either enrich or diminish their ability to teach science effectively. Similar to the findings regarding school climate, there was a clear between-school difference with regard to the availability of social resources such that teachers at School B reported having a variety of social resources that seemed to be lacking at School A. For instance, early career teachers at School B spoke of the ways in which other more experienced teachers had served as mentors and helped them develop new science teaching strategies.

In contrast, one interview participant with three years experience teaching at School A described a lack of social support (3/14/11):

> They just gave me the textbooks and the teacher editions and later the kits and expected me to figure it out. I had never taught science before and I was totally overwhelmed. It was good to have the materials, I'm not complaining, but what I really needed was to talk to someone about how they use it in their classrooms, like to see what they've found to work, but it seemed like everyone was so focused on other things that they wouldn't have time to help me out.

This perceived lack of support described by one teacher at School B was consistent with focus group participants' descriptions of their school's general approach to science education in which individual teachers are generally left to determine whether and how they will teach science with little collaboration with other teachers. Although some teachers didn't see this lack of collaboration or support as a problem, highlighting the benefits of such autonomy, others noted that their science teaching would benefit from more support and encouragement. Specifically, several teachers noted the difficulty of teaching science in a school that, as one teacher put it, "has a lot of science-phobes - some teachers seem to really not like teaching science at all" (Focus Group, 2/23/11). Conversely, teachers at School A and a number of survey respondents explained that other teachers' enthusiasm for science and support from other teachers and administrators as contextual factors that enhanced their science instruction. For instance, one interview participant described how a mentor teacher inspires her and other teachers to become more invested in her science teaching (4/7/11):

> "I taught science before and I liked it, but Ms. _________ has really helped me take it to the next level. I learn a lot from her and I really get excited about revising my lessons and making them better each year. I know a lot of us look up to her that way. I think she's done wonders for science here."

Indeed, this teacher's accolades for her mentor were echoed by teachers in her school focus group who mentioned the same mentor teacher as someone they look to for science teaching ideas, with one teacher describing her as possessing "an excitement for science that's contagious. If you see her teach or talk to her, you can't help wanting to be better" (Focus Group, 3/10/11).

Although the Core Knowledge teachers participating in this study agreed that they possess the tangible, material resources they need to teach science effectively, the survey, focus group, and interview data described here provide clear evidence that such tangible resources are not enough. According to the Core Knowledge teachers who participated in this study, effective science teaching also requires intangible resources such as time and support from other teachers and administrators. Time, as detailed in Research Question 2, is a crucial resource for science instruction and one that the majority of Core Knowledge teachers perceive to be scarce in their schools. Social resources, and particularly support and leadership from other teachers and administrators at their school, emerged as a key factor influencing teachers beliefs about their school context. Teachers who expressed positive context beliefs tended to describe collaboration, mentoring, and support from other teachers as aspects of their school context whereas teachers who expressed negative context beliefs often drew attention to a lack of such social resources.

Teacher and administrator support. As indicated in teachers' perspectives on school climate, there were between school variations in teachers' perceptions of support for science among other teachers and administrators at their schools. At School A, several teachers agreed that while the school administration did not necessarily value science to the same degree as other subject areas, teachers were free to implement whatever science lessons they'd like within their individual classrooms. Regarding this tendency, one teacher stated that "it [science] isn't a main focus, its not like they are looking for it but as long as we get through everything else, we can pretty much do as we want" (Focus Group, 2/23/11). This statement was substantiated by an interview participant who claimed that she was "pretty much left alone to do what I want when it comes to science" (3/14/11). Although this level of teacher autonomy was cited as an asset by some teachers, others found the lack of active support among school administrators and the rest of the faculty more prohibitive, arguing that unless there was encouragement and incentives for teachers to teach science effectively, the majority of teachers would be content to, as one teacher put it, "keep science in the background" (Focus Group 3/14/11).

Teachers at School B cited the recent professional development initiatives at described above (i.e. peer coaching and observation) as indications that support for science teaching among their school's staff and administration was on the rise. In addition to describing how these changes and the district-led initiative fostered a more "science friendly" school climate, several teachers at School B described improvements in their science teaching as a result of increased support from peers or administrators. The school's instructional coach, in particular, was lauded as a supportive influence that facilitates professional development and dialogue among the staff. One teacher describes the instructional coach's role, stating that (Focus Group, 3/10/11):

> She isn't just there to judge you and tell you what's wrong with your teaching… she's seen it all, so she won't really get on you if it doesn't go right. She really just helps and gives you what you need, if you have an idea you can bounce it off her without feeling like you are being evaluated all the time.

Personal agency belief patterns. The frequency of each personal agency belief pattern by reform model is present Table 11. Among the Core Knowledge teachers whose personal agency belief patterns could be classified, the most common patterns were the Robust (n= 7), Modest (n=6), and Tenacious (n=5) patterns. Evidence for the personal agency belief patterns most commonly demonstrated by Core Knowledge teachers is presented below.

Ford describes the Robust personal agency belief pattern as most adaptive and the "most motivationally powerful" of the ten patterns outlined in the framework. Ford argues that this is because individuals with positive beliefs about their capability and their context are best able to "maintain the expectations that their goals will ultimately be achieved, even in the face of obstacles, difficulties, and failures" (p. 134). This characterization aligns well with comments made by seven teachers in Core Knowledge schools. One survey participant discusses how she embraces the challenges of science teaching, stating that "teaching science is challenging, but that's part of what I love about it. On my best days, when I spend enough time preparing and give my students what they need, I feel like I'm a really good science teacher." The same teacher, in describing her school's approach to science education comments on positive changes in her school context, acknowledging that "things have improved a lot. Now science is just as important as the other subjects. We don't always have enough time, but we have everything we need so there's not really an excuse to ignore it anymore." Of the seven Core Knowledge teachers identified as characterizing the Robust personal agency belief pattern, four teachers were from School A, where, as described above, teachers tended to have relatively positive context beliefs. One of the teachers with Robust personal agency patterns was from School B and the other two teachers were survey participants who did not teach at either of the Core Knowledge schools that participated in interviews and focus groups.

Like teachers with the Robust personal agency belief pattern, those with the Tenacious pattern tended to be highly confident in their capability as science teachers. However, unlike teachers with the Robust PAB pattern, teachers falling into the Tenacious category also acknowledged potential obstacles and limitations within their school context. Ford notes that the major difference between the Robust and Tenacious patterns is that in the Tenacious pattern " some degree of environmental unresponsiveness is viewed as predictable and unsurprising" (p. 135). Ford predicts that this expectation "enables people to prepare in advance, both behaviorally and psychologically, for anticipated obstacles and difficulties" (p.135). Each of the teachers categorized as fitting the Tenacious personal agency belief pattern expressed doubts about the level of support their school could provide for science teaching but maintained that they were capable of providing effective science instruction. For instance, one veteran teacher acknowledged inconsistency in her school context, but attributes her capability to years of experience. Other teachers exhibiting this pattern spoke of the importance of autonomy and their determination to exercise their own professional judgment within their individual classrooms in spite of limitations imposed at the school or district level. Consistent with comments made in her school's focus group discussion, one particularly tenacious interview participant emphasized that science teaching was a matter left to individual teacher discretion rather than being a school-wide priority. She goes on to describe her commitment to science teaching within this context stating, "I'd teach science all day if I could, I don't really care if they want us to focus on prep or whatever, I love it like the kids do and I think its my strength, or one of them…but that's just me, it really depends on the teacher" (4/7/11).

Six teachers whose moderate beliefs in their capability were coupled with relatively positive context beliefs were classified as exhibiting the Modest personal agency belief pattern. Ford notes that the Modest personal agency belief pattern differs from the Tenacious pattern in that "the self is regarded as somewhat more fallible and the context is seen as a source of strength rather than a potential obstacle" (p.135). This viewpoint was evident in one third grade teachers' description of her science teaching practices. Asked to describe a typical science lesson in her classroom, this teacher noted that she would likely be teaching lessons developed by colleagues because she "wasn't the best at putting science lessons together" (Interview, 3/14/11). In describing her approach to science teaching, she replied that "I don't really have an approach, still workin' on that since I'm more of a math person, but I just do what I can with what I've got." Nonetheless, this teacher described herself as relatively successful science teacher and attributes her success to collaboration with other teachers at her grade level. She discusses her students' achievement in science, sharing that "my kids did great this year, the whole grade did really, I feel good about how we are doing…mainly because we did shared planning and were able to work through all the standards."

Relatively few Core Knowledge teachers could be classified as exemplifying the less adaptive Self-Doubting (n=2), Antagonistic (n=3), and Discouraged (n=1) patterns. Consistent with Ford's framework, two teachers with moderate or neutral beliefs about the supportiveness of their school context and negative beliefs about their capability were classified as exhibiting the Self-Doubting. Three teachers were classified as having the Antagonistic PAB pattern. All three of these teachers (two focus group participants' and on interview participant) were from School A where, as described above, teachers tended to provide negative comments regarding their school context.

Personal Agency Beliefs in International Baccalaureate Schools

This section summarizes the personal agency beliefs reported by teachers in International Baccalaureate schools. Following findings pertaining to teachers' capability and context beliefs, the specific personal agency belief patterns evidenced by teachers in International Baccalaureate schools are described.

Capability beliefs. With few exceptions, the International Baccalaureate teachers who participated in this study evinced positive capability beliefs. Table 10 presents the frequency with which teachers' statements regarding their capability were coded as high, moderate, or low. Examining these frequencies, we see that the majority of statements made by International Baccalaureate teachers regarding their science teaching ability were coded as exemplifying high capability beliefs and few statements reflected negative capability beliefs. For International Baccalaureate teachers, the themes of inquiry oriented teaching, collaboration, and student engagement were apparent in the qualitative data. Again, I also examined the attributions teachers made regarding the source of their capability.

Inquiry oriented teaching. Teachers at both International Baccalaureate schools referenced inquiry oriented teaching as an indicator of science teaching capability. Teachers who spoke highly of themselves as science teachers cited their ability to design and implement meaningful inquiry activities, whereas the few less experienced teachers with more moderate assessments of their science teaching ability tended to report less success implementing inquiry oriented activities. Although there were clear differences between schools in the degree to which teachers actually enacted inquiry oriented teaching, as documented in Research Question 1 regarding science teaching practices, teachers at both schools were unanimous in their endorsement of inquiry oriented teaching and clearly stated the approach as their "goal-state" for their science teaching. One second year teacher described her growth as a science teacher in terms of her ability to increase the proportion of inquiry oriented lessons she teachers, "I'm pretty good now, I'd say about half of my lessons involve students' doing hands-on, inquiry sort of stuff. I'd like to get to where almost all of them do because that's really how kids learn it best" (Focus Group, 2/4/11). The remarks of one teacher at School B who was particularly disappointed in her science teaching are illustrative. In describing her challenges with science teaching, she states (Focus Group, 3/24/11):

> I feel like I'm doing a pretty lousy job…like really pretty inadequate job with really teaching science. I don't do enough hands-on. I don't do enough activities, hardly any inquiry at all. I don't do enough of pretty much everything. But given the time restraints and being realistic, I don't foresee it changing anytime soon.

> With IB I know we are supposed to be integrating it, doing the inquiry, but I'm not there yet.

Here, the teacher frames her success as a science teacher in terms of the extent to which she is engaging students in hands-on and inquiry activities. Although she clearly recognizes that inquiry is an intended goal of the IB model, she also believes that she is ill-equipped to realize this goal, in part because of what she perceives to be enduring limitations of her school context, which will be described in more detail below.

One dimension of inquiry oriented teaching that teachers' tended to relate to their capability was the ability to facilitate student-centered learning. One International Baccalaureate teacher frames her capability in terms of the student-centered approach (Interview, 3/17/11):

> It's really kind of ironic, I guess. My best science teaching, I mean when I really felt like I 'got it' and went from being just pretty good to really my best is when I let go, when let the students start to really be involved in the process….I mean, they were always involved, but I mean really letting them take some control of what we do, really design ways to explore and answer questions that they have, not just what's already in the kit."

The notion that effective science teachers allow students to help determine the course of their own science learning was debated by teachers during the focus group discussion at School B (Focus Group, 3/24/11):

> Teacher 1: I mean, the best teachers, I think they actually do less.
>
> Teacher 2: What do you mean, less?

Teacher 1: Well, not less overall, just less in the lesson - like the students get a choice on what they do, the teacher doesn't design an experiment and give it to them

Teacher 3: Right, the kids come up with it…but, really, not just the labs, with IB its more like whatever questions kids have, if you are doing it right, you help figure out how to incorporate them in the unit.

Teacher 2: I get that's the goal, great. But I don't know if it's doable, I mean if its so student centered you can miss the standards

Teacher 1: So, that's why I think it's the best teachers that pull it off. I'm not there yet but I try - its a matter of planning it out and figuring out where's there's room to have less structure so its more of an exploration than students just following directions.

Interestingly, the ways in which teachers discussed their capability varied between the two International Baccalaureate schools. At School A, when teachers discussed their growth as science teachers, they were quite specific, mentioning particular strategies, methods, or resources. For instance, one teacher shared examples of lab activities she learned at a national conference. Another teacher discussed his efforts to encourage students to engage in "scientific argumentation" in order to "provide a more rigorous experience" for his 5th grade students (Focus Group, 2/4/11). He elaborated, stating that:

There's no reason kids can't really get into it, really have to defend their methods and conclusions the way scientists do. That's how I see my job these days, my job is to get them to look as much like real scientists as possible.

In contrast, at School B, teachers made more general statements regarding their capability as science teachers. One interview participant, for example, stated that she was “stronger now with IB, I’m doing more hands-on, more inquiry with students” (Interview, 3/31/11). Asked to elaborate on her ability to facilitate such activities, the teacher stated that she is focusing on “not using the textbook so much” (3/31/11). When asked to describe what made their science teaching successful, other teachers at School B cited general pedagogical strengths such as classroom management, differentiating instruction, and conducting formative assessments.

Collaboration. Another prominent theme within International Baccalaureate teachers’ discussions of their science teaching efficacy was the role of collaboration. In addition to viewing collaboration as a valuable aspect of their school context (described further in the discussion of context beliefs below), teachers cited the ability to collaborate with colleagues, students, school leaders, and families as a skill indicative of effective science teaching.

One area where collaboration was especially valued was in the lesson planning process. Teachers at School A, in particular, described their growth as science teachers in terms of their ability to work with one other to create and recreate science units for their students. One teacher notes (Focus Group, 2/4/11):

If you can’t combine ideas, I mean stay open to ideas from your grade level or wherever they come from, your teaching will suffer. We are constantly talking out and comparing ideas to figure out what’s going to work best.

Consistent with school-level differences in teachers’ perspectives on inquiry described above, the level of collaboration described by teachers at School A was envisioned as a goal by teachers at School B. For instance, one interview participant at School B predicted that her science teaching would "really take off" once her school "gets the hang of the planning process" (3/31/11).

Teachers also discussed how their efficacy as science teachers was related to participation in collaborative professional development efforts, such as peer observation and peer coaching. At School B, teachers described how in the current school year the administration had implemented a peer observation program that required each teacher to observe several science lessons in one of their colleague's classrooms. Teachers noted that although they were initially underwhelmed by the requirement and saw it as "just another thing we have to do", they ultimately found that it validated and improved their science teaching (Focus Group, 3/31/11). For instance, one teacher describes the connection between the peer observation experience and her science teaching efficacy (Focus Group, 3/31/11):

> You know, you just do your thing, teach the best you can and sometimes you don't realize that you are doing something new or creative, something that could really move kids along…. At first it was hard, it is any time someone, anyone and sometimes especially another teacher, anytime they are watching and critiquing what you do, but also after we talked and I saw other teachers start to use my ideas, it made me realize "yeah, I'm pretty good at this."'

School A utilized a different model in which individual teachers were selected as "coaches" to attend conferences, workshops, and other professional development opportunities and then share what they learned back to colleagues at the school site. Whether or not teachers were selected to serve as coaches, many teachers comments regarding their capability referenced participation in the program. One teacher stated that "though we can't all go, hearing back from a workshop gives me a lot of ideas so it's almost as good as going myself" (Focus Group, 2/4/11).

Another area where collaboration was seen as an asset for science teaching was in the ability to involve community members and leverage community resources to advance science teaching and learning. At School A, one teacher describes how she worked with the school administration to incorporate a community garden into plans for the school's new building (Focus Group, 2/4/11):

> One thing I'm proud of, one that I think makes a difference for science here, is the garden. Where they built it, since it's on a hill, we had to make sure to plan the right space for the garden. I didn't really have to convince them that we needed it, but I just thought it was important to make sure it happened the right way.

Similarly, teachers on one grade level team spoke proudly of their joint effort to start a recycling program at the school. One teacher describes this program in relation to his science teaching noting that (Focus Group, 2/4/11):

> You have to lead by example. You can't tell kids science is all around and just keep it all in the classroom. When students saw that their teachers cared about this and they got together to do something, they were more interested and we did a whole unit on conservation…I still think that's one of our best units.

At School B teachers also spoke of the ability to identify and leverage resources for the school community as a factor related to their science teaching capability. However, in contrast to teachers at School A ,who described ways in which they extended their classroom science teaching through collaboration, teachers at School B recounted their joint efforts to protect or reallocate existing science resources to support classroom teaching. For instance, one teacher who saw herself as a successful science teacher discussed the ways in which she advocated for science education at the school (Interview, 3/31/11):

> Sometimes being a good teacher means you gotta fight a little, you know stand up for what you know your students need….so a couple years ago when they tried to cut the schedule, to make us to focus on test prep more, I had to say 'wait a minute, that's not gonna work, they need science too'…so we got the grade together and we decided to come up with a schedule we thought would work.

That this teacher sees engaging in such advocacy to protect science time in the school's schedule as an example of "being a good science teacher" highlights the extent to which collaboration is considered, by some IB teachers, to be an important facet of effective science teaching.

Student engagement. Student engagement was another indicator of effective science teaching commonly referenced by International Baccalaureate teachers. Similar to the response pattern for inquiry-oriented teaching theme detailed above, teachers who saw themselves as effective science teachers often referred to their ability to engage students in science, whereas many teachers who were more doubtful about their science teaching ability mentioned student engagement as a particular concern. For several teachers, increasing student engagement in science was highlighted as the primary challenge preventing them from achieving their potential as science teachers. For instance, one teacher at School B who describes herself as "a pretty good science teacher" notes that "I'd be great if I could just get them into it, you know, get the kids excited about science" (Interview, 3/31/11). Likewise, IB teachers with high capability often invoked student engagement as one of their particular strengths. One interview participant's description of a successful science lesson illustrates this pattern (3/17/11):

> I know I've done my job when…of course, there's learning, they get it… but there's also that spark, the kids are really engaged, they want to know more…they keep asking questions even after the assignment is done. I'd rather have them miss some of the vocab…. they can always pick that up, just as long as they leave the lesson more excited than they were at the beginning.

In one particularly compelling exchange during a school focus group discussion, two teachers counsel a colleague who is having difficulty engaging students (Focus Group, 3/24/11):

> Teacher 1: Everyone keeps saying their students love science, they can't wait to get to it, but I… it's not that way in my room. That's my biggest issue. They'll do what I say and they do fine on the test, but I just don't see them jumping up and down for it, like really having fun like I want them to.
>
> Teacher 2: Well, they don't always have *that* much fun. (Laughs). It's more about the process, once they get a taste for it…
>
> Teacher 3: Right…it's not a science party or anything. It's just that I think there's something satisfying, you know really neat, it feels good and its fun when you have a question and you get to figure it out.
>
> Teacher 1: True…but what if they don't feel that.
>
> Teacher 2: What do you mean?

Teacher 1: What if they have the question, like you said, and I let them figure it out but then its just like “ok, I have the answer, what do we do next?” (long pause)

Teacher 3: So maybe it’s the questions they are asking. If its not a challenging question, if they don’t get into it deeper and realize ‘oh, I didn’t know that’ or ‘I wonder what would happen if…’, well then would they get excited the same, I don’t know.

Teacher 2: Yeah. I think it’s all in how you put the problem to them, and how much they are challenged. So if I have students come up with questions about insects and they just want to know some basic fact like how many legs do they have or what do they eat, they might not get into that.

Teacher 1: So how do you get them to ask better questions?

Teacher 2: hmmm. How do I do that? (Laughs). It’s just a habit now so it’s hard to say, but I guess I sometimes just ask “why” or “how come” or try to get them to ask “why” questions. That usually works.

Teacher 3: That’s so true. “Why does a spider have 8 legs?” is way more interesting, right? For kids that need to be challenged, that may be the way to go.

In addition to serving as an example of collaboration and mentoring described previously, this exchange highlights the relationship between student engagement and capability among many of the IB teachers who participated in this study. Here, Teacher 1 who had previously described teaching as “not the best in science” admits that fostering excitement for science is her “biggest issue”. Teachers 2 and 3 go on to offer advice on engaging students through inquiry and, specifically, on creating the conditions for students to ask and pursue answers to questions that pique their curiosity. The link between Teacher 3's capability beliefs and her ability to engage students is apparent in the comment that "creating space" for such curiosity is something that happens in "the best lessons". Similarly, Teacher 2 speaks of her strategy of engaging students by moving beyond simple factual questions by asking "Why?" and "How come?" as a habit that "usually works". Thus, in the context of this mentoring between teachers, student engagement clearly emerges as one indicator of effective science teaching that is valued by IB teachers.

Teachers' capability attributions. Across schools and data-sources, many teachers drew an explicit connection between their science teaching efficacy and their school's implementation of the International Baccalaureate reform model. Teachers with high and moderate capability beliefs cited many ways in which the IB model had led to further development in their ability to teach science well. In addition to highlighting the ways in which the IB model facilitates inquiry, collaboration, and student engagement, as described above, teachers made more general comments about the ways in which the IB model has had a positive impact on their development as science teachers. For instance, one teacher noted that she appreciates how IB has allowed her to "build on what I was doing, to make my lessons fresh and more relevant to the students" (Focus Group, 2/4/11). Another teacher with moderate capability beliefs praised the model for its rigor, stating that "with IB, it's not the easy way to teach…it's challenging for teachers and students but in a good way so it feels good that I'm getting a feel for it now" (Focus Group, 3/24/11). The two IB teachers at School B who expressed negative capability beliefs attributed their difficulties to the school's previous reform model

(Success for All) and to the pressures of accountability policy, but also shared that they saw some potential for improvement in their science teaching with further implementation of the IB model.

Although teachers' capability attributions often referenced the IB reform model, teachers also attributed their science teaching ability (or lack of science teaching ability) to a number of other factors. These included professional development accessed at the school level and at state and national conferences, mentoring from colleagues, and years of teaching experience. Not surprisingly, teachers attributed their effective science teaching to participating in professional development, mentoring, and acquiring teaching experience. In contrast, the few teachers who expressed negative capability beliefs attributed their difficulties to a lack of mentoring and experience. Additionally, teachers at School B described how accountability policy, and standardized testing, in particular, has served as disincentives for improving their science teaching. For instance, one teacher states that "as a teacher we want to do better and teach all the subjects as best as we can, and I think I'm pretty solid, but I will say that the areas where I focus and worry the most have been where there's the high stakes, where the kids really have to show off on those tests…I care about science too but it hasn't been where the pressure is" (Focus Group, 3/24/11).

Context beliefs. Overall, as indicated in Table 10, IB teachers tended to express positive beliefs regarding the supportiveness of their school contexts. Within survey responses, interviews, and focus group discussions, teachers described numerous contextual factors at their schools that they believed supported effective science teaching. Three main themes emerged form the analysis of statements related to teachers' context beliefs: support from other teachers and administrators, the availability of time and material resources for science teaching, and opportunities to participate in professional development activities. Qualitative data related to each of these themes is summarized below.

School climate. When speaking of their school's approach to science education, teachers at IB schools tended to emphasize the ways in which their school's climate was conducive to student-centered inquiry. At School A, in particular, teachers described several characteristics of their school's "science friendly" climate. These characteristics included flexibility with regard to certain aspects of the school's organization and functioning (schedule, curriculum, class size) and what one teacher described as a "relaxed, child-friendly atmosphere" (Interview, 3/17/11).

Regarding the flexibility of school organization, teachers noted that although the teachers and students adhere to a general school schedule each day, it is not uncommon for individual teachers or classrooms to adapt their schedules to accommodate science activities. Teachers noted that most often such changes in the schedule correspond with their IB units such that the time allocated to science activities may vary from day to day or week to week, depending on the unit. Teachers saw this flexibility in the school schedule as an indicator of their school's prioritization of science education, a perspective evident in one teachers' explanation that (Focus Group, 2/4/11):

> We don't put subjects in 30 or 60 minute boxes just to stick to a routine. The routine is there, of course, but it's just a guide so if one experiment or a whole unit that has more science takes longer and goes into "math" time, it's not the end of the world. If it's important to make that time, we do it.

A similar degree of flexibility was noted with regard to curriculum. In both focus groups and interviews, teachers described how the units they created were “living documents” that were continually adapted and refined. One fifth grade teacher at School A described how he conducted small group discussions with his students at the end of each year to gather their input on each of the units and ideas for future units. Teachers also noted that collaboration within and across grade levels enabled students a wider variety of science learning experiences. For instance, although students typically participate in activities within their individual classrooms, teachers noted that under some circumstances, students have participated in learning activities in classrooms or grade levels other than their own.

Regarding the “relaxed, child-friendly” atmosphere described by teachers at School A, teachers referenced the school’s physical appearance as well as the school community’s overall commitment to creating a fun, positive learning environment. For instance, teachers described how when the school was remodeled, students were asked to provide input and help decorate their classrooms. In describing the “relaxed” learning environment, teachers noted that theirs was a school where students were generally well behaved and did not require strict rules and routines. One teacher elaborates, stating that “of course we have rules and there are expectations for how kids should behave, and there will be a few kids who test it but most are really quite good, so this can be a place where kids get to be kids. We don’t expect them to be silent or to sit still and I think most teachers see how some of the best learning happens as students are at play.” Interestingly, this relaxed atmosphere was also noted by teachers at School B who had the opportunity to visit School A. Although teachers at School B described their school climate as less relaxed and certainly less student centered, they did express the view that this was the sort of school climate they envision for their school. Several teachers specifically referenced their observations at School A and noted that they expected the full implementation of the IB model to result in a more student-centered learning environment. For instance, on teacher recalls her impressions of the school (Focus Group, 3/24/11):

> When we saw what it looked like there (at School A) it was like 'oh, that's what they mean'… it seemed a little chaotic at first, there was just so much going on and the kids were all over doing things, but I think it's just 'cuz we aren't used to it like that, after a while it was like ' oh, that's what it looks like".

Another of the primary aspects of school climate highlighted by IB teachers was the extent to which members of the school community had consistent philosophies about teaching and learning. Teachers spoke of consistency both generally in terms of whether teachers shared ideas about how children learn and certain strategies and classroom practices and more specifically in terms of whether teachers shared a commitment to the IB model. Although the consistency of teaching philosophies emerged as a common theme among survey respondents and teachers at both IB schools, the extent to which teachers reported that teachers at their schools possessed a shared vision about teaching and learning varied by school. Teachers at School A noted that there were still a few teachers in the school who continue to resist a more inquiry oriented approach to teaching, but that, overall, teachers held very similar teaching philosophies. One teacher at School A describes this consistency and how it contributes to collaboration at her school (Interview, 3/17/11):

> At some schools, I know this because I was at one before this, you have to be careful about sharing what you do because everyone isn't always on the same page but here it's different because really, we all have similar ideas about how we want to teach so you aren't afraid to share your ideas or ask for some help if you get stuck.

Teachers at school B saw inconsistency in teaching philosophies among the teaching staff as an obstacle. Although participating teachers at School B generally endorsed what was repeatedly referred to as "the IB way" or "the IB philosophy", they were quick to report that there were other teachers at the school who did not share their views on science teaching and learning. According to one teacher at School B, "there are certain teachers and grades that are with it, but you know there's a few, maybe more than a few really, that aren't helpful at all since they don't care about IB and still just want to do it their way" (Interview, 3/31/11). This inconsistency was confirmed within the school's focus group discussion. In the following exchange, teachers describe reluctance among the school's staff to embrace the IB philosophy after having had negative experiences with other reform models (3/24/11):

> Teacher 1: You have to understand that this isn't our first time around with this.
>
> Teacher 2: With the models, she means.. If you've been here for a while you know we've had a few and teachers were pretty skeptical about it, about bringing in another one.
>
> Teacher 1: After SFA especially, which we didn't really like because it was so scripted, teachers really wanted some say…

Teacher 2: We wanted to do our own thing for a minute, you know, so its been hard for everyone to get back into wanting to get on the same page with IB again.

Teacher 1: It's like, what's it called… PTSD, right…(laughs)

Teacher 2: (laughing) kind of is, like we need some time to get over that last one.

Here we see that within one school that has adopted but not fully implemented the IB model, consistency across the staff's teaching and learning philosophies remains a concern. Importantly, teachers attributed this lack of coherence to reluctance to embrace yet another reform model rather than a result of their school's adoption of the IB model, in particular. Teachers at School B who did explicitly endorse the IB model praised the school climate they observed at School A and expressed their desire to transition to a similar student-centered, inquiry oriented school climate as their school's implementation of the IB model proceeds. Taken together, teachers' perspectives on their school climate suggest that a flexible, student-centered environment where teachers' have a shared philosophy of teaching and learning may be supported, if not explicitly promoted, by the IB model.

The availability of resources. Without exception, IB teachers affirmed that they had access to what they believed to be quality instructional resources for science teaching. Material resources teachers noted include textbooks and supplemental printed material (science education journals, magazines), a variety of technology tools for both teacher and student use (i.e. Microscopes, calculators, laptops, probes and sensors), science kits with supplies for labs and inquiry projects, live specimens, and models representing scientific concepts (i.e. Skeletons, topographic maps). Although teachers noted that occasionally they designed lessons that required special supplies and equipment that may not be readily available, they noted that they can often rely on administrators or parents to help with special requests. The only complaint with regard to the availability of material resources came from one teacher at School B who, in her interview, noted that the supplies included in science kits provided by the district were not always delivered or replenished in a timely fashion.

Teachers at IB schools cited time as an important instructional resource. Because Research Question 2 explores the issue of time allocation in depth, here I will briefly highlight findings that specifically relate teachers' context beliefs with their perspectives on the availability of time for science. Again, between-school differences were apparent in teachers' beliefs related to the availability of time for science. At School A, teachers acknowledged that protecting time for science was an ongoing challenge; however, they also highlighted ways in which their school has been able to protect instructional time for science. Primary among these efforts is the integration of science with other subject areas through interdisciplinary units. Teachers at School A described additional strategies for preserving science time included extending learning time through after-school science programs, involving parents and other members of the school community as tutors, and focusing on the most time-consuming subject matter. Regarding this last strategy, teachers discussed the time consuming nature of science instruction and the notion that addressing students' misconceptions often requires several varied experiences with science concepts. Given this reality of science learning, teachers at School A reported that they maximize instructional time by planning to "circle back" to difficult concepts over the course of the year in order to provide students with additional opportunities to enrich their understanding (Focus Group, 2/4/11). For example, one first grade teacher discussed how difficult it was for her students to conceptually differentiate living and non-living things and noted that she was glad she could find time for a variety of activities to address this difficult concept over the course of the academic year. In contrast to this flexible allocation of time at School A, teachers at School B were more likely to report that they lack the time necessary for quality science instruction. In particular, teachers noted that the daily class schedule did not permit sufficient time for science instruction and that they were given inadequate time to plan for their science teaching. Teachers at School B attributed this lack of time, in large part, to their school's continued emphasis on standardized testing and test preparation.

Teacher and administrator support. With a few notable exceptions, teachers at IB schools tended to report a high level of support from their colleagues and school administrators. Teachers at School A and those from other schools who participated in the online survey reported productive, collaborative relationships with colleagues and strong support for science teaching from school administrators. For instance, in describing her school's approach to science education, one survey participant lauded her principal's leadership, stating that "we've come such a long way with science. Our principal, Mr. ________ has a lot to do with it since he's the one who has really instilled that science is a focus for us" (Focus Group, 2/4/11). A number of other teachers described specific ways in which their school administrators have encouraged effective science teaching. These efforts included forming teacher committees to lead unit planning and school-wide science events, implementing peer coaching in which teachers observe and mentor one another, and securing science teaching materials and investing in permanent science equipment and classrooms. Regarding support among other teachers, many of the IB teachers who participated in this study, and especially those at School A, reported that other teachers at their school were highly supportive of their science teaching goals. Teachers highlighted the collaborative unit planning process and the ways in which teachers at each grade level worked together to refine their interdisciplinary units each year. Several teachers saw this collaboration as indispensable, noting that they couldn't imagine developing their units on their own without the support of their grade level colleagues.

In spite of this high overall level of support, teachers at School B expressed some concerns regarding support available for science teaching at their school. Although interview and focus group participants at School B did report that their school principal expressed support for science teaching, teachers noted several ways in which actual support from administrators fell short. For example, teachers expressed disappointment regarding a recent decision to eliminate the Science Specialist position at their school. One focus group participant who had previously held the position noted that providing a Science Specialist meant that all students were guaranteed quality science instruction at least two times each week. Additionally, teachers reported that it remained difficult to obtain support from administrators for their participation in professional development activities, such as State and National Conferences, that were in addition to those provided by the district and school-wide International Baccalaureate trainings. Regarding support from other colleagues, teachers at School B highlighted that although they have been able to form productive relationships with certain mentors and colleagues at their grade levels, investment in the school's science teaching goals and the IB reform model remains uneven across the school. Consistent with some teachers' view that their science teaching was likely to improve with further implementation of the IB model, several teachers at School B were optimistic that support among their colleagues would increase as the school gained additional experience with the model. This optimism is evident when one interview participant from School B quotes Maya Angelou (3/31/11):

> When you know better you do better, you've heard that, right?… I don't think they are..I don't see a lot of teachers that are just 'anti-science' or that they don't want IB at all, I think there's just a learning curve here where some teachers just don't really know what to do yet, but I think once they know they will do better"

Personal Agency Belief Patterns

The frequency of each personal agency belief pattern by reform model and is presented in Table 11. Among the International Baccalaureate teachers whose personal agency belief patterns could be classified, the most common patterns were the Robust (n= 15) and Modest (n=8) patterns. Evidence for the personal agency belief patterns most commonly demonstrated by International Baccalaureate teachers is presented below.

Many International Baccalaureate teachers exemplified the Robust personal agency belief pattern. In particular, teachers commonly made statements indicating that they "maintain the expectations that their goals will ultimately be achieved, even in the face of obstacles, difficulties, and failures" (Ford, 1992, p. 134). These statements often concerned teachers' ability to teach science effectively in spite of it being, according to teachers, an inherently difficult subject area to teach. For example, one interview participant comments on her successes as a science teacher, stating "if you can teach science well, I think you can teach anything…it can be so tough to really understand the content at a deep level and then to get students there, but over the past couple years I've really felt great about what I'm doing and my students are doing so well" (3/17/11). This confidence in spite of the challenge of teaching science was evident in one survey respondent's assessment of her development as a science teacher: "When I first started teaching 6 years ago, science was the toughest subject. Now I feel almost like an expert, like I understand how kids learn – it's still a challenging job but there isn't really any science concept that I feel like I can't teach." Of the fifteen IB teachers identified as characterizing the Robust personal agency belief pattern, six teachers were from School A, where, as described above, teachers tended to have relatively positive context beliefs and high capability beliefs. Three of the teachers with Robust personal agency patterns were from School B and the remaining six teachers were survey participants who did not teach at either of the IB schools that participated in interviews and focus groups.

Eight teachers whose moderate beliefs in their capability were coupled with relatively positive context beliefs were classified as exhibiting the Modest personal agency belief pattern. Teachers who exemplified the Modest personal agency belief pattern tended to highlight ways in which their school context enriched their science teaching. For example, one teacher at School B that "I'm always learning and trying new things – that's the good thing here, now we have the freedom to do that – but there are times when I know I could do much better" (Interview, 3/31/11). Although this teacher clearly believes she has room to grow, she cites the freedom afforded by her school context as a factor that allows her to continue developing as a science teacher. Other teachers exhibiting the Modest personal agency belief pattern noted specific challenges or shortcomings and named aspects of their school context that they are utilizing to address them. For instance, one teacher discussed how observing colleagues at her school is helping her incorporate more inquiry into her science lessons (Interview, 3/31/11):

> I'm getting there, with the students really being responsible for the experiments, the whole idea is to start with the questions students have, but its been easier said than done for me since I came from a more traditional background… but once you see it, like when I go to Ms. __________ Room, it takes the mystery out and I start to feel like I can go in that direction more.

Relatively few IB teachers could be classified as exemplifying the less adaptive Tenacious (n=2) and Self-Doubting (n=1) personal agency belief pattern. Consistent with Ford's framework, two teachers with moderate or neutral beliefs about the supportiveness of their school context and strong beliefs about their capability were classified as Tenacious. Both of these teachers stated that teaching science was among their strongpoints as a teacher but also indicated mixed feelings regarding their schools' ability to support their science teaching. For instance, one interview participant discusses the importance of believing in her science teaching in spite of other teachers' resistance to IB (3/31/11):

> If I was giving advice to a new teacher at my school, I'd say don't be afraid to do what you think is best– we're just starting to get into IB and doing more science but there's a lot of change and not everyone is on the same page, but you can't let that get to you. I know what I'm doing so I just have to do what is right for my students.

Only one IB teacher exhibited the self-doubting personal agency belief pattern. This teacher, whose negative capability beliefs, described earlier in this section, were evident in the statement that "I feel like I'm doing a pretty lousy job" also provided statements indicating moderate context beliefs (Focus Group, 3/24/11). Specifically, this teacher was acutely aware of certain limitations within her school context, especially time constraints and the perception of limited support from administrators and colleagues, while also noting aspects of the school context that supported her science teaching (i.e. the availability of materials).

Personal Agency Beliefs Across Reform Models

Capability beliefs. Across reform models, teachers tended to express positive capability beliefs regarding their science teaching. When speaking of their science teaching ability, the majority of teachers in each of the reform models reported that they possessed either moderate or high ability to teach science and relatively few teachers evinced negative Capability beliefs.

Although teachers within the three reform models did not differ considerably in their self- reported levels of Capability for science teaching (i.e. high, moderate, or low), there were variations in the content of teachers' Capability beliefs across reform models. Examining the themes that emerged from the qualitative analysis of survey, interview, and focus group data, we see that Direct Instruction teachers emphasized student test performance and content knowledge mastery when discussing their efficacy as science teachers. Core Knowledge teachers also discussed content knowledge mastery, but also highlighted curriculum coverage and inquiry oriented teaching as indicators of their science teaching Capability. For International Baccalaureate teachers, inquiry oriented teaching, along with collaboration and student engagement were cited as evidence of their science teaching capability. Thus, while teachers across the three comprehensive school reform models generally believed that they were effective science teachers, there appear to be potential differences in the criteria by which they are assessing their own science teaching. Importantly, while these criteria provide insight into teachers' beliefs about what constitutes effective science teaching, these beliefs may not reflect practices that are *actually* indicative of effective science teaching. For example, DI teachers' pride in student test performance and Core Knowledge teachers' attention to curriculum coverage do not necessarily align with the goal of fostering student understanding of science concepts.

Similar differences were seen in the patterns of capability belief attributions provided by teachers in the three reform models. Of particular relevance for this study is the degree to which teachers attributed their efficacy as science teachers to their school's reform model. Interestingly, Direct Instruction teachers with positive capability beliefs tended to attribute their success to factors and experiences outside of their school setting (i.e. Family influences, education, conference participation); however, many of the Direct Instruction teachers who expressed negative capability beliefs implicated the Direct Instruction model as one factor limiting their efficacy as science teachers. Core Knowledge teachers varied in the degree to which they attributed their efficacy to the reform model, with teachers at one school suggesting the model enabled them to be more effective and teachers at another school describing ways in which the model limited their efficacy of science teachers. Core Knowledge teachers with negative capability beliefs tended to attribute their lack of science teaching success to factors beyond the school, including accountability policy (i.e. NCLB), the State standardized testing program, and district reform policies. International Baccalaureate teachers were more likely than teachers in the other two reform models to attribute their efficacy as science teachers to their experiences with the reform model. International Baccalaureate teachers with high and moderate capability beliefs pointed to a number of ways in which the model enriched their ability to teach science including the models emphasis on inquiry, collaboration, and student engagement.

Context beliefs. There were clear differences in teachers' context beliefs across comprehensive school reform models. Consistent with the pilot study data in which teachers from Direct Instruction schools scored lower than teachers in the other two reform models on a measure of context beliefs, the Direct Instruction teachers participating in this study were far more likely than teachers in the other two reform models to provide negative statements regarding the supportiveness of their school contexts. Specifically, in schools implementing the Direct Instruction reform model, teachers complained that their schools lack a climate conducive to science teaching and learning, adequate time for science instruction, and leadership and administrative support for science teaching and learning. Further, many teachers drew an explicit connection between their school's lack of support for science teaching and implementation of the Direct Instruction reform model.

Context beliefs among teachers in Core Knowledge schools were more mixed with some teachers describing a clear lack of support for science teaching at their schools and others reporting a more "science-friendly" school context. This variation in context beliefs among Core Knowledge teachers manifested both between and within each of the schools that participated in the study, with certain teachers contending that their school context supported their science teaching goals while other teachers complained of inadequate support. In contrast to teachers in the Direct Instruction reform model, few Core Knowledge teachers explicitly mentioned the reform model when discussing the supportiveness of their school context. Instead, Core Knowledge teachers tended to reference other factors at the school and district level, such as specific efforts led by school administrators, the District's Math-Science Initiative, when discussing both positive and negative aspects of their science teaching context.

International Baccalaureate teachers' context beliefs were more positive than those expressed by Direct Instruction teachers and the majority of Core Knowledge teachers. Although doubts about the supportiveness of their school climate lingered among teachers at a school that recently adopted the reform model, experienced International Baccalaureate teachers were nearly unanimous in their positive context beliefs. Among these teachers, the IB program was often cited as a key component of their school's science teaching context. In particular, a flexible, "child-friendly" school climate along with ample teacher and administrative support and the availability of time and resources were noted by teachers as aspects of the school context that were conducive to effective science teaching.

Personal agency belief patterns across reform models. The variation in context and capability beliefs described above mirrors the variation in personal agency belief patterns that emerged across the three reform models. Ford's taxonomy was utilized to code interview, focus group, and survey data and assign teachers to one of ten personal agency belief patterns. As illustrated in Table 11, the Robust and Modest personal agency belief pattern, described by Ford as two of the more adaptive patterns, were most common among International Baccalaureate teachers and were evidenced by a number of Core Knowledge teachers, but were quite uncommon among Direct Instruction teachers. Likewise, the less adaptive Accepting, Antagonistic, Discouraged, and Hopeless personal agency belief patterns occurred among a number of Direct Instruction teachers, were less common among Core Knowledge teachers, and did not occur among International Baccalaureate teachers. This distribution of teachers personal agency belief patterns across the three reform models, suggest potentially significant differences in the extent to which teachers believe that, given their science teaching ability and the supportiveness of their school context, they will be able to realize their science teaching goals.

CHAPTER 5: DISCUSSION

The implications of school reform policies for science teaching and learning have been emphasized by numerous scholars (Apple, 2006; Gamoran et al., 2003, Goldston, 2005; Jones et. al., 1999, Shaver et. al., 2007; Tate, 2001). However, few researchers have investigated how specific approaches to school reform, such as the implementation of comprehensive school reform models, interact with efforts to improve science education in urban elementary schools. Indeed, research examining the compatibility of comprehensive school reform and science education reform is virtually non-existent. This study represents the first to explore elementary science education within the context of three popular comprehensive school reform models. Specifically, within the context of the Direct Instruction, Core Knowledge, and International Baccalaureate reform models, the study examines three key areas of elementary science education: 1) science teaching practices, 2) the allocation of time for science education, and 3) elementary teachers' personal agency beliefs.

The following discussion is comprised of three sections. The first section discusses salient findings and suggestions for future research regarding each research question. The second section extends this discussion by employing the Knapp & Plecki (2001) framework to further examine the ways in which the three reform models interact with science education reform within the teaching policy environments involved in this study. Recall that the Knapp & Plecki (2001) framework defines four dimensions that can be used to characterize the teaching policy environment: coherence, comprehensiveness, intrusiveness, and stability. These four dimensions provide a useful framework for analyzing the compatibility of each of three comprehensive school reform models examined with current science education reform efforts. Following this discussion based on the Knapp & Plecki framework, the limitations of the study and implications for research, policy, and practice are discussed.

Research Question #1: Science Teaching Practices

The analyses of focus group, interview, survey, and observation data converge to suggest variations in science teaching practices by reform model. Key differences across reform models emerged in three areas: 1) the integration of science with other subject areas, 2) the degree to which science is student versus teacher centered, and 3) the extent to which science instruction focuses on traditional science learning goals such as mastering "science facts" and vocabulary versus attaining conceptual understanding. Results pertaining to each of these variations in science teaching practices are discussed below.

The integration of science with other subject areas was reported more frequently by teachers implementing the Core Knowledge and International Baccalaureate reform models than by teachers implementing the Direct Instruction model. While it is disheartening that Direct Instruction teachers who recognize the value in interdisciplinary learning have few opportunities to integrate science with other subject areas, that Direct Instruction teachers so rarely reported this practice is not surprising given the model's emphasis on scripted literacy instruction. Designing and delivering instruction that integrates science with other subject areas requires a degree of teacher autonomy and creativity that are simply not permitted by the Direct Instruction model. Turning to the Core Knowledge and International Baccalaureate models, where teachers more commonly reported integrating science with other subject areas, differences emerged concerning teacher motivation for interdisciplinary learning. A sub-set of Core Knowledge teachers viewed integration across subject areas primarily as a practical matter, a way to cover more curriculum standards in less time. Interestingly, these teachers also tended to report a more traditional, teacher centered approach to science instruction.

For other Core Knowledge teachers and the majority of International Baccalaureate teachers, the primary motivations for interdisciplinary learning were instructional in nature. These teachers may have also recognized the efficiency of integrating science with other subject areas, but they emphasized the benefits of student learning resulting from interdisciplinary learning such as enriched student understanding, increased student engagement, and allowing students to make connections to "real-world" issues. Future research in this area should continue examining the ways in which various reform models either hinder or facilitate interdisciplinary learning. Additionally, studies that examine teachers' motivations for interdisciplinary learning may lend further insight into the relationship between teachers' instructional decision-making and the teaching policy.

Other key areas of variation among reform models were the extent to which teachers' practice was student-centered versus teacher-centered and traditional versus inquiry oriented. Interestingly, across reform models teachers frequently used terms such as "inquiry" and "hands-on activities" to describe their approach to science instruction. However, observation data and teachers' elaborations on their science teaching practices suggests that a more traditional, teacher-directed approach predominates in the majority of Direct Instruction classrooms and may also be common in Core Knowledge classrooms. Specifically, the data suggest a lack of attention to students' prior knowledge and questions, few opportunities for students to design or determine the direction of inquiry or scientific discourse, and an emphasis on fact-learning, test preparation, and vocabulary acquisition over authentic inquiry. Although some teachers who are relatively new to the IB model also reported traditional, teacher-centered instruction, experienced IB teachers clearly articulated a student-centered approach to science teaching in which students' questions serve as the starting point for inquiry activities and students are engaged in designing investigations in order to explore their questions and ideas.

Again, these differences in science teaching practices among reform models are hardly surprising given the philosophical underpinnings of each model. The Core Knowledge model includes no guidance for *how* science should be taught, only a prescription of *what* science content students need to know. Thus, Core Knowledge teachers predictably highlight the importance of vocabulary acquisition and fact learning. Without an imperative or cohesive vision for engaging students in inquiry, Core Knowledge teachers are left to do so at their discretion. Similarly, student-centered instruction would require Direct Instruction teachers to literally go off script to teach content that is not supported by their reform model and to do so in a fashion that is antithetical to scripted instruction. Indeed, of the 37 Direct Instruction teachers who participated in this study, two teachers did stand out as exceptions for their willingness to deviate from the script. In both cases, teachers drew a direct contract between their student-centered, inquiry-oriented approach to science teaching and the expectations of the Direct Instruction reform model. As teachers continue to struggle with the conflicting demands within their teaching policy environments, much could be learned form studies examining the strategies of successful "rogue" teachers who deliberately adapt policy and programs in order to meet the science learning needs of their students.

Research Question #2: The Allocation of Time for Science

The fact that time for science within the elementary school day is scarce is not news. Teachers, school leaders, parents, and researchers have repeatedly drawn attention to the narrowing of the elementary school curriculum and the consequent depletion of time for science at the elementary level (Apple, 2006; Pringle & Carrier-Martin, 2005; Spillane et. al., 2001). However, exactly *why* and *how* science has been placed on the back burner at so many elementary schools remain important questions. This study begins to lend insight into the allocation of time for science by examining variations across comprehensive reform models.

Although teachers in all three reform models report limited time for science, observation data and teachers estimates of the amount of time spent in their classrooms show this scarcity to be quite uneven across reform models. Teachers in International Baccalaureate schools reported spending nearly twice as much time on science each week as Core Knowledge teachers and nearly four times as much time as Direct Instruction teachers. That there were such wide variations in time allocated for science among the three reform models suggests that a school's choice of comprehensive school reform model may have important implications for the amount of time available for students and teachers to engage in science, begging the question: what features of each reform model may either limit or protect time for science?

In the case Direct Instruction, reform model documents and classroom observations confirm teacher reports that implementation of the model's scripted reading lessons can consume the vast majority of instructional time each school day, leaving little or no time for other subjects or activities, including science. Indeed, only Direct Instruction teachers explicitly named their school's reform model as one of the main factors that limited time for science at their school. Not only does the Direct Instruction model appear to limit time for science, teachers at both schools participating in this study reported that this limitation remains largely unacknowledged at their schools. For example, several Direct Instruction teachers reported that time designated for science instruction on school schedules is often spent on Direct Instruction activities. Teachers also described how they are encouraged to display projects students complete at home as if they were completed in the classroom and required to submit and post weekly plans for science lessons knowing that they would rarely, if ever, find time to implement these lessons. In these ways, it appears that in at least some Direct Instruction schools, deliberate efforts are made to maintain the appearance that science instruction is occurring on a regular basis when, in reality, it rarely occurs at all. Any effort to provide all students opportunities for quality science instruction must include an honest assessment of the resources, including time, that can be devoted to the cause. When schools fail to acknowledge or deliberately obscure the fact that time for science is being limited, they send a strong message that science teaching and learning is a formality rather than a priority. The end result, of course, is perpetually limited opportunities for students to learn science. Future studies should further investigate and document the actual allocation of time for science learning in schools implementing Direct Instruction and similar reform models. More in depth investigation into school level practices and policies may lend further insight into whether and to what extent limitations on time for science are acknowledged and perpetuated and how teachers working in such schools can work to reclaim time for science.

Unlike Direct Instruction teachers, teachers implementing the Core Knowledge model did not attribute the scarcity of time for science to their reform model. In fact, Core Knowledge teachers rarely mentioned their reform model unless explicitly asked to comment on it. Instead, Core knowledge teachers tended to refer to factors beyond their school to explain what they perceived to be a lack of adequate time for science instruction. Primary among these factors were the pressures and expectations placed on teachers as a result of the State's standardized testing program. Consistent with previous research describing teachers concerns about the effects of standardized testing programs (Pringle & Carrier-Martin, 2005; Shaver, Cuevas, Lee & Avalos, 2007), Core Knowledge teachers attributed decreased time spent on science to the prioritization of other "high-stakes" subjects (e.g. Math, Reading, Language Arts) that factor into the school's measures of Annual Yearly Progress under the No Child Left Behind Act. Although they did not mention the reform model explicitly in their discussion of time allocated for science, interview and focus group data, along with a review of Core Knowledge documents, highlight aspects of the Core Knowledge model that may provide some protection for science time. First, unlike the Direct Instruction model that includes virtually no science content, the Core Knowledge Sequence clearly outlines science content students should learn at each grade level and the amount of science content within the Core Knowledge sequence appears to be more or less in balance with content in other subject areas. Although the model falls short of promoting inquiry and activities designed to build conceptual understanding, the mere inclusion of science content within the sequence means that students in Core Knowledge schools may be more likely to be exposed to science content than students participating in the Direct Instruction model. Second, because the model does not prescribe teaching methods or a certain approach to science teaching, teachers have the freedom to design their own science lessons and to integrate science with other subject areas. Indeed, Core Knowledge teachers described integration across subject areas as a time-saving strategy that enabled them to cover more content than they would if they taught each subject in isolation.

Teachers at the two International Baccalaureate schools that participated in this study differed in their perspectives on the allocation of time for science education. Although, overall, teachers at IB schools tended to devote significantly more time to science instruction than teachers in the other reform models, teachers at both schools acknowledged that finding adequate time to teach science remains a challenge. However, key differences emerged in the reasons teachers gave for the scarcity of time for science at their schools. Teachers at a school that had implemented the reform model for over six years spoke of instructional considerations - the inherently difficult and time consuming nature of science learning and the challenge of finding adequate time to cover the breadth of topics included in State and National standards. This perspective contrasts with that of the majority of teachers at the second school whose concerns about the effects of standardized testing and accountability policies echoed those of the Core Knowledge teachers. That the perspectives of teachers at these schools differed so clearly highlights the unique school context at individual schools in which reform models are implemented.

The International Baccalaureate model's prioritization of inquiry and student-centered learning and it's emphasis on interdisciplinary teaching and learning would seem to serve as protective factors that may help conserve time for science. However, International Baccalaureate schools are clearly not immune to the pressures of accountability policies and standardized testing. In this study, it appears that these pressures were felt unevenly, with teachers at one school expressing clear frustration regarding the effects of standardized testing and teachers at the other school attributing the lack of time for science to factors unrelated to the accountability policy. These differential concerns may reflect differences in demographics, school culture, and the dramatically different histories regarding standardized testing at the two schools. Indeed, one can imagine that implementing the International Baccalaureate model at a school where the majority of students come from low income households and where pressures to meet AYP are so great that administrators have been found to engage in cheating on standardized tests is a very different proposition than implementing the model in a school serving predominantly upper-middle class students who enter school on or above grade level and routinely excel on standardized tests. To the extent that the International Baccalaureate reform model manages to protect time for science learning in elementary schools, that protection should be unconditional and be extended to any school that adopts the model. The degree to which the model can withstand the pressures of standardized testing and accountability policy to be successfully implemented in high need, urban schools is an important topic for future research.

Research Question #3: Personal Agency Beliefs

According to Ford's theoretical framework, an individual's ultimate expectations for whether they will be able to accomplish a goal are a product of their beliefs about their ability and their beliefs about the supportiveness of their context. For teachers in this study, expectations regarding science teaching potential depend not only on their capability beliefs, but also on their beliefs about the extent to which their school context, including the comprehensive school reform models implemented at their school, affords adequate support for science teaching.

Consistent with Ford's framework, this study illustrates the interactive effects of context and capability beliefs. Overall, across reform models, teachers tended to provide positive assessments of their capability beliefs. Whether they were enacting the scripted Direct Instruction model, the content-focused Core Knowledge model, or the inquiry-oriented International Baccalaureate model, teachers tended to believe they could capably teach science. However, consistent with pilot study data, there were clear variations in teachers' context beliefs such that Direct Instruction teachers evinced relatively negative context beliefs in contrast to the mixed context beliefs reported by Core Knowledge teachers and the generally positive context beliefs reported by teachers at International Baccalaureate schools. Thus, the spectrum of context beliefs across reform models appears to interact with teachers' overall positive capability beliefs to produce variation in personal agency beliefs across reform models. Although the personal agency belief patterns of many teachers who participated in this study could not be classified, the finding that the most adaptive of Ford's patterns were most common among International Baccalaureate teachers, who tended to speak positively of their school context, and least common among Direct Instruction teachers, who tended to have negative context beliefs, provides some empirical support for Ford’s taxonomy.

That capability beliefs were relatively consistent across reform models suggests that teachers’ ultimate expectancies about whether they can achieve their science learning goals (i.e. personal agency beliefs) may have much to do with their beliefs about the supportiveness of their school context. Indeed, within this study, there were teachers with strong beliefs in their capability who ultimately doubted that they would accomplish their science teaching goals because they had serious concerns about supportiveness of their school context. Conversely, there were clear examples of teachers with moderate or even negative assessments of their science teaching ability who expressed high hopes for their future science teaching because they saw their school context as supportive. Because teachers’ context beliefs emerged as a key determinant of their personal agency beliefs, the following discussion pays particular attention to the results concerning teachers’ context beliefs.

Future research should further examine the relationship between personal agency belief patterns and comprehensive school reform models. Specifically, researchers interested in this area should consider conducting more in depth qualitative case studies focused on individual teachers with various personal agency belief patterns and their experiences within different school reform contexts. Such research would both provide an opportunity to explore the validity of the personal agency belief patterns proposed by Ford and shed light on the ways in which comprehensive school reform models (or other reform efforts) may influence teachers personal agency belief patterns.

Comprehensive School Reform and the Teaching Policy Environment

Coherence

Of the four dimensions of the teaching policy environment outlined by Knapp & Plecki (2001), the dimension of coherence is particularly germane when considering the compatibility of various comprehensive school reform models and efforts to improve science education. Recall that Knapp & Plecki (2001) define coherence as the extent to which the different strands of policy offer mutually supportive guidance for science teaching. By examining the perspectives of elementary teachers charged with simultaneously implementing their school's comprehensive school reform model and science education reform, this study lends insight into the challenges that arise when different and sometimes conflicting policies interact at the school level. For example, in describing their science teaching practices and the amount of time devoted to planning instruction, Core Knowledge teachers discussed the challenge of aligning the Core Knowledge Sequence with science content included in the State Science Standards and district provided Scope and Sequence documents. This lack of alignment suggests a degree of incoherence between the Core Knowledge model and the district's Math-Science Initiative. While this inconsistency between the reform model and State and District curriculum policy was seen as problematic by some teachers, teachers at Core Knowledge schools were ultimately able to reconcile these conflicting curricular demands.

Whereas Core Knowledge teachers seem to have found ways to work through any incoherence between their reform model and science education reform, teachers enacting the Direct Instruction reform model articulated what may be considered a more serious, fundamental incoherence between their reform model and science education reform. For instance, teachers discussed many ways in which they found the school climate fostered by the reform model to prohibit the mode of science teaching and learning encouraged by the district's science initiative. In addition to severely limiting time available for science instruction, reform model documents and remarks from teachers at Direct Instruction schools provide strong evidence that the model's emphasis on scripted, teacher-centered instruction and regimented student behavior are in conflict with a more inquiry oriented approach to science teaching and learning.

At the other end of the spectrum, teachers in the International Baccalaureate model emphasized the many ways in which implementing the model and teaching inquiry oriented science go hand in hand. In particular, the reform model's emphasis on student-centered, interdisciplinary inquiry aligns with the requirements of science education reform including the district's current initiative. Indeed, any incoherence that existed between the International Baccalaureate model and other policies were due to the IB reform model going *beyond* the expectations implied by initiatives and policies at the district, state, and national levels. For instance, experienced IB teachers at one school critiqued the Essential Labs offered through the district initiative, stating that they were far too basic and did not provide sufficient opportunities for students to engage in extended project-based inquiry learning. Thus, not only does the International Baccalaureate reform model appear to promote the goals of science education reform, teacher reports suggest that, when fully realized, the IB model may have the capacity to elevate science teaching beyond the expectations set by current science reform agendas.

Thus, to varying degrees, teachers in the Core Knowledge and Direct Instruction reform models appear to be working in somewhat incoherent teaching policy environments that tend to send mixed messages about science education. In Core Knowledge schools, these mixed messages tend to relate to the sequencing of content for students at various grade levels, with the Core Knowledge sequence prescribing content that is not always in sync with the demands of other curricular policies (i.e. State Standards, the district's Scope and Sequence). In Direct Instruction schools, teachers struggle to reconcile their reform model's time-consuming teacher-centered script with the more inquiry oriented approach to teaching and learning called for by science education reform. In contrast, teachers with experience implementing the International Baccalaureate model report a much more coherent teaching policy environment in which common goals and assumptions about science teaching and learning are consistent with the other policy influences at work within the school.

Comprehensiveness

Knapp and Plecki (2001) define comprehensiveness is the degree to which the array of policies touch all aspects of science teachers' work. Teachers' descriptions of their science teaching contexts suggest the three so-called *comprehensive* school reform models may vary in the degree to which they are indeed comprehensive, according to Knapp & Plecki's definition. While the scripted Direct Instruction model certainly dictates many of the aspects of how elementary teachers interact with the curriculum, their students, and each other, the near complete lack of a science component means that Direct Instruction teachers can successfully implement the model without teaching science at all. This lack of science within the model may explain why Direct Instruction teachers provided so few positive comments regarding their science teaching context. Because the reform model has so little potential to enrich or even inform science teaching and learning, its primary effect is limiting. Data gathered from teachers enacting the Core Knowledge model suggest their teaching policy environments may be considered moderately comprehensive in that the Core Knowledge Sequence and State Standards define the science content that should be covered without providing guidance regarding the mode of science teaching and learning that should be undertaken. Indeed, more than teachers in the other two reform models, Core Knowledge teachers reported that science teaching practices varied widely within their schools and depended largely on whether and how individual teachers chose to teach science. The International Baccalaureate reform model stands out as potentially being the most comprehensive of the three investigated in this study. Although many aspects of the IB model had yet to permeate the work of teachers at one school in its second year of implementation, teachers with more experience implementing the IB model described numerous ways in which the model serves as a cornerstone of their science instruction. The collaborative planning process, the integration of content across subject areas, and the emphasis on student-led inquiry are among the facets of the model that define IB teachers' daily work. Additionally, the frequency with which teachers at both International Baccalaureate schools referred to there being an "IB way" of teaching suggests that teachers saw the model as a comprehensive approach to instruction, even if they had not yet fully implemented the model themselves.

Intrusiveness

Similar to the comprehensiveness suggested by each of the models, they also seem to vary in similar ways concerning their intrusiveness. Recall that Knapp & Plecki (2001) describe intrusiveness as the extent to which policies are designed and enacted in ways that make immediate demands on science teachers versus exerting little or no pressure on teacher practice. Again, the Direct Instruction model, while intrusive with regard to many other aspects of teaching and learning in other subject areas, makes no demands on teachers regarding science instruction. However, given the ways in which the model may engender a school context that actively discourages science teaching and learning, it could be said that the model is potentially intrusive because it places pressure on teachers *not* to prioritize science education. Given that Core Knowledge teachers were much less likely to explicitly mention their reform model versus other policies (i.e. NCLB, State Standards) when discussing their school context, it seems that the Core Knowledge reform model may be considered the least intrusive of the three examined here. Whereas the Direct Instruction model can be characterized as intrusive in the negative sense, the International Baccalaureate model may be considered a positive intrusion. Although teachers who are experienced with the model report having significant freedom when it comes to the actual planning and implementation of their science instruction, this appears to be freedom that is built into the International Baccalaureate model rather than freedom from the model itself. Indeed, experienced IB teachers discuss the model as the driving force of their instruction and the challenges reported by teachers who are new to the model suggest that it does place a certain pressure on teachers to adapt their science instruction.

Stability

Although this was not a longitudinal study, teachers' reflections on their science teaching experience provide some insight into the dimension of stability, defined by Knapp and Plecki (2001) as the extent to which policies remain constant within a teaching policy environment. In particular, teacher comments suggest the duration of comprehensive school reform model implementation and the transition from one comprehensive school reform model to another as potentially important factors influencing teachers' beliefs and science teaching practices. Differences observed between the two participating schools implementing the International Baccalaureate model appeared to be related to the stability of the teaching policy environment in each school. At one school where at the time of the study the IB model had been implemented for six years, teachers reported and observed science teaching practices aligned well with the student-centered, inquiry-based vision of the model. In contrast, at an International Baccalaureate school that was only in its second year of implementation, teachers struggled to reconcile certain key components of the model with their existing practices. For instances, although interdisciplinary learning is a hallmark of the International Baccalaureate model, the 5th grade teachers at this school reported that they continued departmentalized instruction with each academic subject taught more or less in isolation. Interestingly, in discussing the school's adoption of the reform model, one teacher attributed the reluctance of some teachers to "buy in" to the IB model, in part, to what she perceived as teachers' recent negative experiences with another reform model (Success for All). Thus, it seems plausible that, although, overall, teachers tended to favor the adoption of their new reform model, the transition from the much more scripted Success For All model to the International Baccalaureate model may have created a degree of instability in the teaching policy environment at this school. More in depth studies that examine schools undergoing the transition from one reform model to another could further clarify whether and in what ways the stability in the teaching policy environment may matter for science teaching and learning.

Limitations

Four limitations were germane to this study. First, the findings of this study are somewhat limited by its exclusive focus on teachers' perspectives. Although teachers are central to reform model implementation and the enactment of science education reforms, school and district administrators, students, and other school staff are also involved. School administrators, in particular, may be able to provide insight into how reform models are adopted and how they interact with other school and district initiatives at work within the school teaching policy environment.

Second, although I attempted to include schools with comparable years of reform model implementation, due to the number of available schools implementing each reform model within the district, this was not possible in every case. Although five of the schools have achieved what can be considered full implementation, one of the International Baccalaureate schools was in its second year of implementation at the time of this study and teachers reported that they were still in the beginning stages of implementation. Consequently, the practices reported by teachers at this school may not necessarily reflect those intended by the model.

Third, although classroom observations were conducted in one school implementing each reform model, these observations occurred over a relatively short time frame. Otherwise, the study relies on teachers' self-reports of their teaching practices, time devoted to science in their classrooms, and their beliefs about their science teaching and their school context. I attempted to address this limitation through triangulation among multiple data sources (interviews, focus groups, survey responses, and documents); however, as with the use of any self-report methodology, it is not always possible to verify participants' responses. Added to this issue is the notion that beliefs, in particular, are thought to be difficult for individuals to recognize and articulate (Pajares, 1997; Kagan, 1990).

Finally, because participants in focus groups, interviews, and observations were self-selected, their perspectives may not be representative. Although this study does not attempt to generalize the experience of participants beyond their particular school contexts, several teachers did offer their perspectives with the caveat that it was not necessarily typical of their schools. Specifically, there is the possibility that teaching practices reported by teachers in this study differ in significant ways from other teachers at their schools. Given that teachers who participated in the anonymous survey portion of the study reported spending even less time on science than was reported by teachers in the interviews and focus groups, it is quite possible that data provided by self-selected focus group and interview participants may actually overestimate the amount of time devoted to science.

Implications for Research, Policy, and Practice

Although many have expressed concern regarding the effects of school reform policy on science education, few researchers have directly examined the specific implications of comprehensive school reform models and science education reform. This study represents a first step in what could be a fruitful research agenda further examining how comprehensive school reform models interact with science education reform at the school level. Future studies should continue to examine how teachers, as agents of policy implementation, make decisions about how and whether to teach science, how to balance the demands of science education reform and comprehensive school reform, and how to reconcile conflicts that may arise between the philosophies underpinning these programs.

The findings of this study suggest that the reform model a school chooses to adopt may have important implications for science teaching and learning. Although many of the models listed in the catalogue of available reform models have been evaluated for their impact on student achievement in reading, mathematics, and language arts, outside of this study, little has been done to determine whether various reform models support effective science instruction. Therefore, a clear need exists for additional studies that evaluate comprehensive school reform models specifically for their effects on science education. In addition to extending this work to investigate the effects of reform models on student achievement in science, future work examining the reform model adoption in diverse school settings could further illuminate the ways in which science teaching and learning are affected, either positively or negatively, by reform model implementation.

By examining capability beliefs in conjunction with context beliefs and in relationship to comprehensive school reform, the study addresses one of the major critiques of previous work on capability and the rationale behind Ford's conception of personal agency beliefs: "self-efficacy beliefs must be context specific and relevant to the behavior under investigation to be useful to researchers and appropriate for empirical study" (Pajares, 1992, p.315). Studies that build on this work to further explore whether and how school reform policies intended to improve science teaching and learning influence teachers' capability beliefs (a.k.a. self-efficacy beliefs) will be an important area of future research.

The findings presented here also provide theoretical support for the two frameworks employed in the study. Specifically, regarding Ford's framework, the findings of this study lend credence to the notion that teachers' expectancies regarding their science teaching potential may be a function of *both* their context and capability beliefs. Among the teachers who participated in this study, there were clear examples of teachers who evinced positive capability beliefs but still doubted their ability to teach science effectively because of what they perceived to be an unsupportive school context. Although some of the teachers who participated in this study could be classified using the ten personal agency belief patterns described by the Ford framework, many teachers could not be classified using Ford's taxonomy. Whether this is an artifact of the data or reflects limitations of the framework is unclear; however, future work in this area may seek to clarify or elaborate on Ford's taxonomy to ensure that it adequately captures the complexity of teachers' context and capability beliefs.

This study also provides support for Knapp & Plecki's framework outlining the various forces and dimensions at work within the teaching policy environment. As evident in the previous discussion, the dimensions of the teaching policy environment defined by the framework (coherence, comprehensiveness, intrusiveness, and stability) provided a useful lens through which to interpret the findings of this study. Researchers utilizing this framework in the future may be interested in further refining these dimensions to detail, in theoretical terms, the ways policies may interact. For instance, Knapp & Plecki provide a clear definition of coherence: the extent to which different strands of policy offer mutually supportive guidance for science teaching. However, the framework does not specify factors that may contribute to coherence or how to discern to what degree a given teaching policy environment is coherent.

This study also has clear practical implications for policy implementation and teacher professional development. Given that teachers varied substantially in their beliefs about their school context, a more flexible approach to professional development and the implementation of science education reform that takes into account potential differences across school and comprehensive school reform models may be warranted. Just as our best teachers consider the needs of their individual students when designing and delivering instruction, districts may need to differentiate science education reform and professional development in order to adapt to the unique teaching policy environments at individual schools. To the extent that comprehensive school reform models intend to affect the same aspects of teaching and learning targeted by science education reform, district and school leaders should consider how science initiatives and reform models are likely to interact at the school level. Identifying school reform models that either complement or conflict with the goals and processes of science education reform may enable more efficient and effective implementation of science education initiatives. While this study provides evidence that the International Baccalaureate model, when fully implemented, may protect time for science instruction and promote a mode of science teaching and learning consistent with the goals of science education reform, successful implementation of the model would require a shift away from the test prep culture and teacher-centered instruction prevalent in many urban elementary schools. On the other hand, the findings of this study raise serious concerns about the compatibility of the Direct Instruction and Core Knowledge reform models and science education reform. School and district leaders who plan to adopt these programs in their schools would be wise to consider whether the models can be implemented without compromising their vision for science teaching and learning.

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Table 1

Focus Group Participant Demographics

Model	School	Teachers	Gender	Ethnicity	Grade Level	Yrs. @ K-5	Years at School	# Science Courses taken in College	How often do you teach science? (Times per wk)	Length of typical Science Lesson
DI	A	T1	F	AA	3	4	4	0	1-2	30
		T2	F	AA	2	9	5	2	3-4	15
		T3	F	W	5	3	3	1	1-2	30
		T4	F	W	3	6	2	2	1-2	30
		T5	M	W	1	3	3	2	<1	30
		T6	F	W	4	2	2	1	1-2	15
	B	T1	F	AA	K	3	4	0	1-2	25
		T2	F	AA	3	5	6	1	1-2	20
		T3	F	AA	3	5	2	2	1-2	30
		T4	F	AA	1	6	3	2	3-4	30
		T5	F	W	2	5	3	1	<1	25
		*T6	F	AA	3	5	5	4	<1	28
		T7	F	AA	1	5	2	1	1-2	35
Core	A	T1	M	W	4	4	1	0	2	45
		T2	F	W	3	3	3	1	3	30
		T3	F	AA	3	3	3	1	2	30
		T4	F	AA	1	2	2	1	2	30
		T5	F	AA	2	15	6	2	3	30
		T6	F	W	5	3	3	1	3	20
		*T7	F	W	3	8	5	2	3	25
	B	T1	F	W	K	3	3	3	2	30
		T2	F	W	1	5	2	1	1-2	30
		T3	F	W	5	2	2	0	2	45
		T4	F	AA	3	2	2	0	4	30
		T5	F	W	1	4	4	2	3	30
IB	A	T1	F	Hispanic	4	8	6	0	3-4	45
		T2	M	W	1	9	5	3	3-4	60
		T3	F	W	3	12	7	3	3-4	45
		*T4	F	W	3	6	6	4	3-4	30
		T5	F	W	4	5	5	0	Daily	45
		T6	F	AA	2	4	4	1	3-4	40
	B	T1	F	AA	5	9	4	0	Daily	45
		T2	F	W	3	6	3	0	3-4	60
		T3	F	AA	3	7	4	1	3-4	45
		T4	F	W	2	3	3	1	Daily	40
		T5	F	AA	1	3	3	3	Daily	45
		T6	F	AA	2	2	2	2	Daily	45

* Teachers participated in classroom observations.

Table 2

Interview Participant Demographics

Reform Model	School	Teachers	Gender	Ethnicity	Grade Level	Yrs. @ K-5	Yrs@School	Science Courses	How often do you teach science? (Times per wk)	Length of typical Science Lesson
DI	A	T1	F	AA	3	3	3	0	1-2	30
		T2	F	AA	2	10	5	1	3-4	15
	B	T1	F	W	1	3	3	1	1-2	30
		T2	M	AA	3	5	3	2	1-2	25
Core	A	T1	F	W	2	3	3	0	3-4	45
		T2	F	AA	3	4	4	2	1-2	30
	B	T1	F	W	5	14	5	0	3-4	45
		T2	F	AA	1	8	2	1	1-2	35
IB	A	T1	F	AA	1	6	3	3	Daily	45
		T2	F	W	2	4	2	2	Daily	45
	B	T1	F	W	2	17	8	2	3-4	60
		T2	F	W	5	5	3	2	3-4	50

Table 3

Survey Participant Demographics

Characteristic	n (%)
Gender	
Female	96 (88)
Male	13 (12)
Race/Ethnicity	
African American	85 (78.0)
Caucasian	19 (17.4)
Hispanic	3 (2.8)
Asian	2 (1.8)
Grade	
Kindergarten	15 (13.8)
1st Grade	20 (18.3)
2nd Grade	18 (16.5)
3rd Grade	25 (22.9)
4th Grade	14 (12.8)
5th Grade	17 (15.6)
College science courses completed	
None	23 (21.1)
1 semester	44 (40.4)
2 semesters	22 (20.2)
3 semesters	5 (4.6)
4 semesters	6 (5.5)
5 or more semesters	8 (7.3)
Comprehensive School Reform Model	
Core Knowledge	19 (17)
Direct Instruction (D.I.)	22 (20)
International Baccalaureate (I.B.)	20 (18)
Pearson Achievement Solutions	15 (14)
Project Grad	17 (16)
Success For All (S.F.A.)	16 (15)

Table 4

Summary of Research Questions, Data Sources, and Methodology

Research Questions	Data Sources	Methodology
1. To what extent do science teaching practices vary across the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?	- Open-ended survey questions - Focus Group - Interviews - Observations	- Triangulation of reported teaching practices in survey responses and focus group interviews with observation data
2. How is time for science education allocated in schools implementing the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?	- Open-ended survey questions - Teacher Questionnaire - Focus Group - Interviews - Documents - Observations	- Content analysis of documents - Descriptive analysis of teachers' time estimates on questionnaire - Triangulation of teacher survey responses, focus group data, and observation data.
3. To what extent do teachers' personal agency beliefs vary across the Core Knowledge, Direct Instruction, and International Baccalaureate reform models?	- Open-ended survey questions - Focus Group - Interviews	- Categorization of teacher survey responses according to Ford's personal agency belief profiles - Triangulation of survey and focus group interview data

Table 5

Reformed teaching observation protocol (RTOP) scores by reform model

RTOP Subscale	Reform Model Core Knowledge		D.I.	International Baccalaureate		
	Lesson 1	Lesson 2	Lesson 1	Lesson 1	Lesson 2	Lesson 3
Lesson Design/Implementation	6	8	1	14	13	18
Content: Propositional Knowledge	14	16	15	18	16	19
Content: Procedural Knowledge	8	11	2	15	14	17
Classroom Culture: Communicative Interactions	9	12	4	16	18	16
Classroom Culture: Student/Teacher Relationship	10	9	6	18	17	20
RTOP Total Score (out of 100)	47	56	28	81	78	90

Table 6

Reported Science Teaching Practices – Representation across Core Knowledge, Direct Instruction, and International Baccalaureate Teachers

Teaching Practice Codes	Core Knowledge		Direct Instruction		International Baccalaureate		Total
1. Prior Knowledge	12	34%	7	18%	22	61%	41
2. Learning Community	3	9%	1	3%	3	8%	7
3. Exploration Precedes Presentation	1	3%	0	0%	4	11%	5
4. Alternative Modes	3	9%	3	8%	0	0%	6
5. Student directed	6	17%	1	3%	26	72%	33
6.Fundamental Concepts	14	40%	9	23%	17	47%	40
7. Coherent Understanding	7	20%	1	3%	14	39%	22
8. Teacher Content Knowledge	6	17%	5	13%	5	14%	16
9. Abstraction	2	6%	3	8%	0	0%	5
10. Connections	14	40%	3	8%	23	64%	40
11. Representation variety	0	0%	0	0%	1	3%	1
12. Hypothesis testing	7	20%	2	5%	11	31%	20
13. Active Engagement	4	11%	4	10%	6	17%	14
14. Student Reflection	4	11%	0	0%	9	25%	13
15. Intellectual Rigor	3	9%	2	5%	7	19%	12
16. Communication variety	0	0%	0	0%	1	3%	1
17. Divergent questions	1	3%	0	0%	2	6%	3
18. Student Talk	7	20%	2	5%	13	36%	22
19. Students directed discourse	3	9%	0	0%	17	47%	20
20. Respectful Climate	4	11%	1	3%	10	28%	15
21. Active participation	3	9%	2	5%	18	50%	23
22. Encourage conjecture	4	11%	1	3%	15	42%	20
23. Patience	0	0%	0	0%	0	0%	0
24. Resource Person	1	3%	1	3%	8	22%	10
25. Teacher as Listener	1	3%	0	0%	4	11%	5
Essential Labs	26	74%	4	10%	9	25%	39
"Hands-on" Activities	20	57%	17	44%	27	75%	64
Take-home projects	16	46%	12	31%	7	19%	35
Science/Engineering Fair	8	23%	3	8%	11	31%	22
Inquiry (unspecified)	24	69%	21	54%	27	75%	72
Integrating Science w/math	22	63%	6	15%	23	64%	51
Integrating Science w/literacy	20	57%	1	3%	21	61%	42
Integration (general)	25	71%	1	3%	27	75%	54
Teacher Lecture/presentation	13	37%	15	38%	2	6%	30
Textbook Reading/assignments	12	34%	21	54%	6	17%	39
Vocabulary learning/acquisition	16	46%	23	59%	4	11%	43
Test Preparation	16	46%	17	44%	3	8%	40
Learning "Scientific Facts"	20	57%	9	23%	2	6%	31

Table 7

Reported Science Teaching Practices – Representation within International Baccalaureate Schools

Teaching Practice Codes	IB School A	IB School B
1. Prior Knowledge	10	2
2. Learning Community	3	0
3. Exploration Precedes Presentation	3	0
4. Alternative Modes	0	0
5. Student directed	9	4
6.Fundamental Concepts	5	5
7. Coherent Understanding	7	3
8. Teacher Content Knowledge	1	2
9. Abstraction	0	0
10. Connections	7	3
11. Representation variety	1	0
12. Hypothesis testing	6	2
13. Active Engagement	3	3
14. Student Reflection	5	2
15. Intellectual Rigor	4	1
16. Communication variety	0	0
17. Divergent questions	0	0
18. Student Talk	6	1
19. Students directed discourse	7	1
20. Respectful Climate	6	3
21. Active participation	6	6
22. Encourage conjecture	6	6
23. Patience	0	0
24. Resource Person	4	0
25. Teacher as Listener	3	0
Essential Labs	4	4
“Hands-on” Activities	9	6
Take-home projects	2	3
Science/Engineering Fair	4	4
Inquiry (unspecified)	9	6
Integrating Science w/math	10	7
Integrating Science w/literacy	10	3
Integration (general)	9	5
Teacher Lecture/presentation	0	2
Textbook Reading/assignments	1	4
Vocabulary learning/acquisition	1	3
Test Preparation	0	3
Learning “Scientific Facts”	0	2

Table 8

Allocation of Time for Science by Reform Model and Data Source

Data Source and Reform Model	N	Average Minutes Daily (SD)	Average Minutes Weekly (SD)	Average # Science Lessons/ Week (SD)
District-wide Survey				
Core Knowledge	19	25.7(8.3)	74.0 (15.24)	3.1 (.99)
Direct Instruction	22	19.4 (11.5)	37.3 (35.3)	1.9 (.81)
International Baccalaureate	20	36.5 (17.7)	142.0 (34.3)	3.9 (.55)
Focus Groups				
Core Knowledge	12	40(10.3)	98 (16.6)	2.6 (.78)
Direct Instruction	13	24(11.5)	70 (17.4)	2.4 (.65)
International Baccalaureate	12	52 (7.8)	168 (34.9)	3.4 (.87)
Interviews				
Core Knowledge	4	31 (6.3)	128 (37.7)	3.0 (.81)
Direct Instruction	4	22 (6.2)	79 (14.4)	2.3 (.50)
International Baccalaureate	4	54 (9.5)	180 (16.3)	3.5 (.58)
Overall (Across Data Sources)				
Core Knowledge	35	31 (10.8)	88 (25.7)	2.9 (.91)
Direct Instruction	39	21 (11.1)	53 (33.4)	2.1 (.75)
International Baccalaureate	37	44(15.2)	155 (58.1)	3.7 (.71)

Table 9

Descriptions of Ford's Ten Personal Agency Belief Patterns

PAB Pattern	Description	Example Statement
Robust (+, S)	Strong and firm in purpose or outlook	"I'm not going to let a few setbacks get me down. I can do anything if I put my mind to it."
Modest (+, M)	Placing a moderate estimate in one's abilities	"I can do pretty well if I'm realistic and stay within my capabilities."
Fragile (+, W)	Intact but easily broken or damaged	"You're going to have to help me – there's no way I can do this on my own."
Tenacious (0,S)	Strength in dealing with challenges/obstacles	"It's not going to be easy, but I can reach my goal if I keep at it and don't let obstacles get to me".
Vulnerable (0, M)	Functioning adequately, but at risk under stress	"Sometimes I think I'll do fine, but other times I fear the worst."
Self-doubting (0, W)	Having a lack of faith in chance for success	"I just know I'm going to blow this."
Accepting (- , S)	Endures difficulties quietly/with courage	"All I can do is accept it and try not to let it get to me."
Antagonistic (- , S)	Actively expresses annoyance/hostility	"I'm not quitting until I make this @*!?$# work!"
Discouraged (- , M)	Feels deprived, but may maintain some confidence/hope	"I just can't seem to get this to work – I might as well start over."
Hopeless (-, W)	Has no expectation for success	"It's nice to think about, but there's no way it could ever happen".

Context Beliefs = Positive (+), Neutral/Variable (0), Negative (-)
Capability Beliefs = Strong (S), Moderate/Variable (M), Weak (W)

Table 10

Frequency of Self-Efficacy and Context Belief Statements Across Reform Models and Data Sources

		Core Knowledge				Direct Instruction				International Baccalaureate			
		Survey	Inter view	Focus Group	To tal	Surve y	Intervie w	Focu s Grou p	Tot al	Surve y	Intervie w	Focu s Grou p	Tot al
Self-Efficacy Beliefs	High	11	2	9	22	6	4	7	17	7	8	20	35
	Moder ate	7	7	9	23	7	3	8	18	2	2	8	12
	Low	3	5	4	12	7	6	7	20	1	0	6	7
Context Beliefs	Positiv e	4	6	6	16	2	0	2	4	6	9	8	23
	Neutra l	5	1	3	9	1	2	1	6	1	2	1	4
	Negati ve	3	3	5	11	9	7	20	36	1	1	0	2

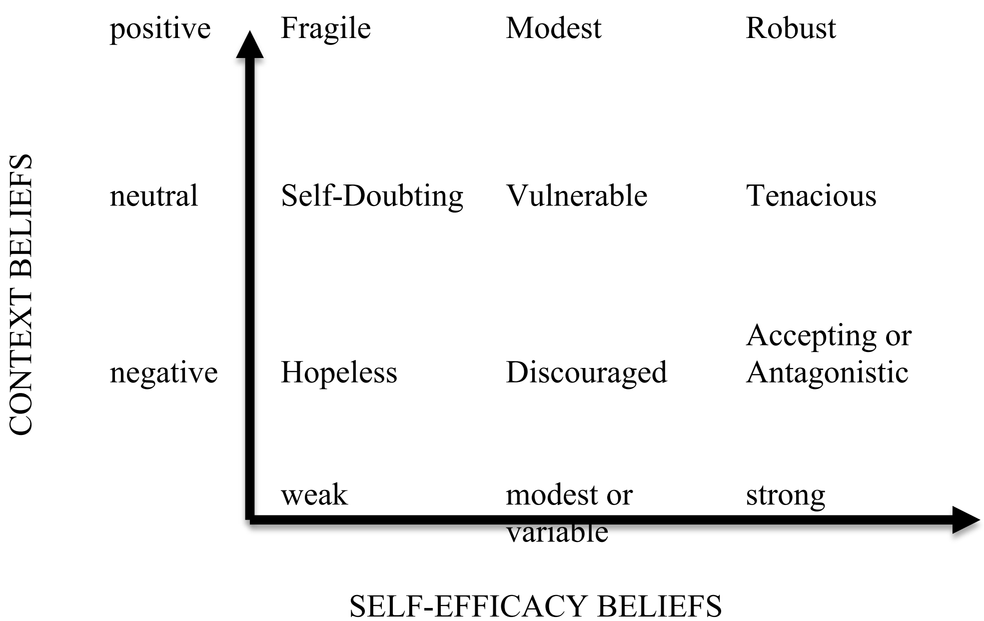
Table 11

Frequency of Personal Agency Belief (PAB) Patterns Across Reform Models

	Core Knowledge	Direct Instruction	International Baccalaureate
Robust	7	2	15
Modest	5	1	8
Fragile	0	1	0
Tenacious	6	3	2
Vulnerable	0	2	0
Self-Doubting	2	0	0
Accepting	0	5	0
Antagonistic	3	6	0
Discouraged	1	6	0
Hopeless	0	4	0
Unclassified	11	9	11

Figure 1

Personal Agency Belief Patterns



(from Haney et. al., 2000, p. 173 adapted from Ford, 1992)

Appendix A
The International Baccalaureate Learner Profile

Trait	Description
Inquirers	They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives.
Knowledgeable	They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.
Thinkers	They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.
Communicators	They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others.
Principled	They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them.
Open-minded	They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience.
Caring	They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment.
Risk-takers	They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs.
Balanced	They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others.
Reflective	They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

From the IB Learner Profile Booklet accessed on www.ibo.org on October 26, 2010.

Appendix B

Focus Group Protocol

Introductions:
Participants introduce themselves and share why they were interested in participating in the focus group.

1. Discussion Starter Questions: To start us off, I'd like you to consider the following questions (posted on flip chart):

    a. What are three words or phrases that describe your experience teaching science at (school name)?
    b. If I were to observe a science lesson in your classroom, what would I see and hear?

Participants discuss these two questions in pairs for a few minutes before discussing with the group. Follow-up question: What informs your practice as a science teacher?

2. How would you describe yourself as a science teacher?
   Follow up: What are your strengths? Challenges? How does your ability to teach science compare to your ability to teach other subjects?

3. What does a typical science lesson look like in your classroom? If I were to visit, what would would I be likely to see?

4. How would you describe your school's approach to science education to someone who is not familiar with the school?

   Follow up: If a new teacher asked you for advice about teaching science at (school name), what would you tell him or her?

5. Tell me about your school's reform model (Core Knowledge, DI, or IB). How do you think your school's reform model has influenced your science teaching and your school's approach to science education?

   Follow-up: Are there other policies that affect either *how* you teach science or *what* you teach in science?

6. Is there anything else you think I need to know in order to understand science education at (school name)?

7. Summary Discussion – 10 minutes -

Appendix C
Contact Summary Form

Focus Group Date _________________ Today's Date ______________

School Site _________________ Number of Participants______
School Contact Name _________________ Data File _________________

1. What were the main issues or themes that struck you during this focus group?

2. Summarize any information, preliminary analysis, reflections pertaining to each research question:

Question 1. Science Teaching Practices	
Question 2. Allocation of time	
Question 3. Personal Agency Beliefs	

3. Paraphrase any memorable, important, revealing quotations:

4. Methodology Comments – Note any potential revisions or changes for future data collection/analysis:

5. Anything else that struck you as salient, interesting, illuminating or important?

Appendix D
Consent Form

Emory University
Division of Educational Studies
Informed Consent

Title: Elementary Teachers' Practical Knowledge about Science Education and Reform
Principal Investigator Jessica Gale, Ph.D. Candidate

Sponsor: National Science Foundation

Introduction/Purpose

I am interested in learning about elementary educators' science teaching experiences and their attitudes toward science education. You are being asked to be in a research study because you are an elementary teacher in Atlanta Public Schools. The purpose of this study is to identify trends in elementary teachers' views about science education, to gain insight into elementary teachers' strategies for implementing science education initiatives, and to examine how school context influences how elementary teachers approach science education. This spring, I plan to conduct focus groups and interviews with approximately 120 teachers. Each focus group and interview will take place at one of a number of elementary schools in the district and include 6 – 10 participants.

Procedure

If you choose to participate in the study, you will be asked questions about your experiences as an elementary educator. The discussion topics in the focus group will include general questions about your school and its approach to science education, your personal views on science education, and your experiences teaching science. You will participate in one focus group discussion with colleagues from your school. The focus group discussion will last approximately 90 minutes. As a group member, you will be able to direct the conversation and to explain why certain aspects are important to you. You can participate as little or as much as you choose and you are free to end your participation at any time. Interviews will last approximately 60 minutes.

The focus group will be moderated by the primary researcher. No information that may personally identify you will be recorded on any of the forms; instead, you will be asked to choose a pseudonym (a name other than your own). The group session will be audio recorded and the recordings will be transcribed to forms that will only include your pseudonym. The recordings will be secured in a locked filing cabinet accessible only by the primary investigator. All audio recordings will be destroyed at the conclusion of the study.

Your information will not be disclosed to anybody who is not part of the study team. All focus group members will be reminded that all information shared in the focus group should remain confidential. There is, however, the possibility that discussions held in the focus group will be disclosed by other group members.

Voluntary Participation
Participation in this study is completely voluntary, and you are free to decline to participate or to stop participation at any time. There are no negative consequences associated with withdrawing from this study.

Risks
There is minimal foreseeable risk associated with this study, although it is possible that you may experience some stress when talking about the topics that emerge as part of the focus group discussion. You have the right to decline to answer any question, for any reason. You have a right to withdraw from the study at any time.

Benefits
While there may be no direct benefit to you from participation in this study, it is hoped that what is learned from this study will have an impact on science education and professional learning in the Atlanta Public Schools district.

Confidentiality
Certain offices and people other than the researcher may look at your study records. Government agencies, Emory employees overseeing proper study conduct may look at your study records. These offices include the Emory Institutional Review Board and the Emory Office of Research Compliance. Study records can also be opened by court order. Emory will keep any research records we produce private to the extent we are required to do so by law. A pseudonym rather than your real name will be used on study records. Your name and other facts that might point to you will not appear when I present this study or publish its results.

Questions
If you have any questions about this study you may email Jessica Gale at jessica.gale@emory.edu. If you have questions about your rights as a participant in this study, you may contact the Emory Institutional Review Board at 404-712-0720 or 877-503-9797. If you are interested in the study findings after all the results are analyzed, you may email Jessica Hammock at jessica.gale@emory.edu.

Consent
I will give you a copy of this consent form to keep. If you are willing to participate in this research, please sign below.

____
Participant's Name

______________________________ ________________
Participant's Signature Date

______________________________ ________________
Person Obtaining Consent Date

Appendix E
Interview Protocol

1. How would you describe yourself as a science teacher? Follow up: What are your strengths? Challenges? How does your ability to teach science compare to your ability to teach other subjects?

2. What does a typical science lesson look like in your classroom? If I were to visit, what would would I be likely to see?

3. What has your science teaching experience taught you about how children learn? How do you think kids best learn science?

4. How would you describe your school's approach to science education to someone who is not familiar with the school?

    a. Follow up: If a new teacher asked you for advice about teaching science at (school name), what would you tell him or her?

5. Tell me about your school's reform model (Core Knowledge, DI, or IB). How do you think your school's reform model has influenced your science teaching and your school's approach to science education?

    a. Follow-up: Are there other policies that affect either *how* you teach science or *what* you teach in science?

6. Is there anything else you think I need to know in order to understand science education at (school name)?

7. Summary Discussion – 10 minutes -

Appendix F
Reformed Teaching Observation Protocol – Sample Items

RTOP Subscale	Sample Items
Lesson design and implementation	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein. The lesson was designed to engage students as members of a learning community. The focus and direction of the lesson was often determined by ideas originating with students.
Content: Propositional knowledge	The lesson involved fundamental concepts of the subject. The lesson promoted strongly coherent conceptual understanding. The teacher had a solid grasp of the subject matter content inherent in the lesson.
Content: Procedural knowledge	Students made predictions, estimations and/or hypotheses and devised means for testing them. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena. Students were reflective about their learning.
Classroom Culture: Communicative Interactions	Students were involved in the communication of their ideas to others using a variety of means and media. Student questions and comments often determined the focus and direction of classroom discourse. There was a climate of respect for what others had to say.
Classroom Culture: Student-teacher relationships	Active participation of students was encouraged and valued. The teacher acted as a resource person, working to support and enhance student investigations. The metaphor "teacher as listener" was very characteristic of this classroom.