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A Longitudinal Analysis of Science Teaching and Learning in Kindergarten and First-Grade

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To my family

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

This study attempted to determine how often science is taught in the early grades as well as the science topics taught in these grades. A related purpose of the study was to determine the relationship between science teaching and students' science achievement. In doing so, the analyses took into consideration the influence of gender, socioeconomic status (SES), and race/ethnicity on children's academic performance in science. By using the Early Childhood Longitudinal Study- Kindergarten class of 1998-99 (ECLS-K) kindergarten and first-grade data files, children's science *Item Response Theory Scores* (*IRT)* and *Academic Rating Scores (ARS)* were examined to measure the relationship between children's early science experiences in schools and their achievement on the "General Knowledge Assessment Battery".

According to this study's findings science teaching and learning in kindergarten level is somewhat limited. Additionally, the science content taught in kindergarten is narrow. The results of cross-sectional and longitudinal multilevel analyses revealed that several student and school level factors can influence young children's science achievement in kindergarten and first-grade. Although there were inconsistent conclusions about male and female students' science achievement as assessed by direct and indirect assessment batteries, there was no association between children's science scores and their gender and the amount or degree of science practices in school. While results of the analyses clearly showed that socioeconomic status (SES) had the most influence on both kindergarten and first-grade children's science achievement, the findings related to the effects of different science practices on science achievement were inconsistent. The results showed that science instruction effects some children's science achievement more than others.

The findings have important implications for policies governing the teaching of science in the early grades. A clear demand exist for extension of science resource materials to include broader topics, more child-selected activities, integration with other subject areas, and more quality time for science teaching and learning in the early grades.

CHAPTER 1

INTRODUCTION

Since the mid 1960’s there has been worldwide (USA, UK, Africa, Australia, New Zealand, Israel, Sri Lanka and Indonesia) interest in the teaching and learning of science in the primary grades (i.e., pre-kindergarten to third-grade). During that time, researchers sought to determine whether: “teaching science at the primary level is worthwhile in terms of its impact on pupils’ later scientific understanding?” (Harlen, 2001, p. 61). Recent research into children’s learning has provided some evidence that early science learning not only helps children to form their ideas, but also offers the potential for addressing and modifying their ideas before they enter higher grades (Davies & Ward, 2003; Harlen, 2001; Ravanis, 2004). Science, however, has been given minimal attention in early childhood classrooms (Dickinson, Burns, Hagen, & Locker, 1997; Johnson, 1999). Consequently, children’s success in science has been an area of concern for many years for educators (Johnson, 1999).

The concern about the quality of science teaching was evident in a report by the National Commission on Mathematics and Science Teaching for the 21st Century (2000). This report directed national attention toward the urgent need to improve students’ performance in mathematics and science. The main message in the report was that students’ performance in science and mathematics was unacceptable. One reason for this was that children in the United States were falling behind in the area of science when compared to children from other nations. The report also claimed that early childhood teachers were ill prepared to incorporate appropriate science experiences into children’s education, and that usually science teaching was absent from early childhood programs.

One of the report’s proposed solutions to the problem was to engage in an aggressive effort to improve the quality of science teaching. The report claimed that too often teachers relied on ineffective teaching strategies (National Commission on Mathematics and Science, 2000). A similar claim was made in the Project 2061 report: the *Dialogue on Early Childhood Science, Mathematics, and Technology Education* (American Association for the Advancement of Science, AAAS, 1998). This publication by the American Association for the Advancement of Science claimed that science teaching was usually absent in early childhood programs. This being the case, then it is possible that additional resources should be directed toward science teaching in the early childhood years. Yet, the nature of science teaching in the early childhood years is unclear, and there is very little empirical evidence to support these claims.

This study attempted to fill this gap by using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-1999 (ECLS-K) to determine the effect of science teaching on kindergarten and first-grade students' science achievement. Specifically, the study examined how often science was taught in kindergarten. Additionally, the data was examined to determine the science topics that were addressed in kindergarten, as well as the instructional strategies and resources that teachers used. Next, children's scores on measures of science learning were examined to determine their progress in science learning, as well as the relationship between classroom instruction and students' learning in science.

In this chapter, the problem that was investigated is explained, and an overview of the theoretical framework is outlined. Second, the purposes and educational significance of the study is discussed. This section is followed by an outline of the research questions, along with definition of key terms used in this study.

Statement of the Problem

Science is generally considered an important subject that should be taught across all grade levels (Lind, 1999; Katz, 1997). Recent reports, however, suggest that children's competence in science is at an unacceptably low standard, especially when compared to students from other nations (National Commission on Mathematics and Science Teaching for the 21st Century; Schroeder, Scott, Tolson, Huang, & Lee, 2007). Furthermore, it is claimed that very little science is taught in the early grades, and that this lack of science teaching could contribute to underachievement in science. Science tends to be a neglected topic in early childhood classrooms because it is “perceived and presented as too formal, too abstract, and too theoretical – in short, too hard for very young children and their teachers” (Johnson, 1999, p.19).

Theoretical Framework/Rationale

Science has always been considered an important subject that should be taught across all grade levels (Lind, 1999; Katz, 1997). It is hardly surprising therefore, that educators and policymakers pay close attention to national and international trends in student performance in science. Concerns have been expressed, for example, about the poor performance of U.S. students in comparison to students from other industrialized countries (National Commission on Mathematics and Science, 2000). Although the United States comes in first in many areas (Day & Yarbrough, 1998), and has long been known as a world leader in science and technology, the overall performance of American students seems to be lagging (National Commission on Mathematics and Science, 2000). This was evident in a recent study conducted by the National Center for Education Statistics, which explored U.S. twelfth-grade students’ mathematics and science achievement in an international context (National Commission on Mathematics and Science, 2000). The results show that American students were placed 16th and 17th in science and mathematics respectively. Similar results were reported in the Third International Mathematics and Science Study (TIMSS), and the National Assessment of Educational Progress (NAEP, the “Nation’s Report Card”). While TIMSS results indicate that U.S. eight-graders scored slightly above the international average in science, the NAEP results show that more than one-third of U.S. students scored below the “basic” level in mathematics and science (National Commission on Mathematics and Science, 2000).

According to the National Research Council (1996), regardless of age, gender, socioeconomic status, cultural or ethnic background and interests, with appropriate learning opportunities, all children can develop the knowledge and skills to achieve an acceptable level of science understanding. This cannot be achieved, however, without access to professional teachers, adequate classroom time, appropriate materials and sources (National Research Council, 1996). Moreover, recent publications (e.g., AAAS, 1989; 1994) have challenged the status quo in science education by publishing specific learning goals throughout grades (K-12). These benchmarks outline “what students should know, understand, and be able to do in the natural sciences over the course of K-12 education” (National Research Council, 1996, p.6).

Numerous strategies have been proposed and, in some cases, implemented in an attempt to improve students’ science performance. For example, following recommendations in the Glenn report (2000) additional professional development was provided for teachers. If students’ science performance is to be improved, then science teaching should be enhanced at all levels, including the primary grades. Arguably, the teaching of science in kindergarten and first-grade is critically important because the knowledge and experiences learned in the early grades can serve as a foundation for future learning (Lind, 1999; Katz, 1997).

Science teaching and learning in the early grades was addressed in detail in a recently published report. The findings from Project 2061 are synthesized in *Dialogue on Early Childhood Science, Mathematics, and Technology Education* (1998). Addressing the needs of children aged 3 to 5, the Project 2061 and subsequent publications have made important contributions to early childhood science. The following ideas were presented in the report:

- Young children are capable of learning more than we had previously thought.
- Mathematics and science are usually absent in early childhood education.
- Early childhood teachers and care givers are often ill prepared to incorporate appropriate science, mathematics, or technology experiences into children’s lives.
- The range of early childhood experiences is vast, and the resources for early childhood education are few and inequitably distributed (p. vi).

Most educators would agree that it is important to teach science in the early grades (Jones, Lake, & Lin, 2008). Science education is mandatory across all grades in today’s educational system. Within this system we ask children to accept scientific ideas that are publicly accepted. This process not only requires that children understand ideas about the natural world, but also the development of conceptual thinking, often times at a higher level than their cognitive levels. If children are going to be successful in learning science then it is important for them to encounter science in the early grades. This is because when children are given developmentally appropriate science activities they can encounter a set of ideas at a practical level. In turn, these activities will help them to understand the same ideas at an abstract level in the future (Davies & Ward, 2003; Ravanis, 2004).

From birth, children want to learn about their environment by poking, pulling, testing, pounding, shaking and experimenting and their early experiences exert a powerful influence on all later ones (Lind, 1999; Katz, 1997). These experiences allow them to engage in scientific thinking long before they enter a classroom. It is somewhat surprising though that when they do start formal schooling, their science learning is limited to learning scientific facts (Wilson, n.d.; Zeece, 1999). At this point, early childhood settings play an important role because the context of science teaching and learning differs in both form and structure from primary and higher grades. The expectation that children learn scientific facts and science history can be appropriate for higher grades, but for young children science learning should not be limited to the learning of scientific facts presented by other (Lind, 1999; Ravanis, 2004; Wilson, n.d.). In short, science in the early grades should be “an active enterprise” (Lind, 1999, p.73). Basically, science instruction in kindergarten should be designed to be a natural part of a child’s daily experiences (Lind, 1999; Ravanis, 2004; Wilson, n.d.). This view is also supported by the National Science Education Standards (National Research Council, 1996) and Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993).

In the early years of schooling, the goal of science education is to develop/support children’s attitudes of curiosity and interest in experimentation. Active and hands-on activities allow children to use and develop a number of science process skills. By using the process skills and conducting their own investigations, children develop an understanding of the products of science (Martin, Sexton, Wagner, & Gerlovich, 1997). Through these process skills, children in the early grades experience various areas of science. These include: life and health science, physical science, and earth science. Life science includes exploration of plants, animals, life cycles, and ecology. The relationships of body parts and their functions, body systems, food, and nutrition are common areas that children study in order to understand health science. During physical science experiences, children explore properties of objects (such as size, weight, shape, and color), force, motion, energy, machines and the states of matter. During earth science studies, children have an opportunity to conduct investigations about the motion of the earth, air, wind, land, weather, rocks, mountains, oceans, and the solar system (Gallenstein, 2003). Clearly, it is important for young children to learn about all areas of science, and they should be presented with a balanced science curriculum. Ultimately, however, the success or failure of science teaching in the early childhood classroom depends on the teacher.

Teachers play an important role by providing children with the required knowledge (Appleton & Kindt, 1999). According to recent literature, teachers' degree of preparedness and their apparent reluctance to teach science have been considered as important factors that tend to turn them away from teaching science. It is often claimed that early childhood teachers have a phobia about teaching science (Abell & Roth, 1992; Appleton, 2003; Carol; Harlen, 1997; Osborne, Simon, & Collins, 2003; Seefeldt & Galper, 2007). Schools, however, have an obligation to meet the needs of students by providing them with access to quality science experiences as well as quality teaching in the primary grades (Appleton, 2003; Huffman & Thomas, 2003). Recognizing this obligation, the Glenn report (National Commission on Mathematics and Science Teaching for the 21st Century, 2000) recommends that in order to improve science teaching in early grades, we need to increase the numbers of highly qualified science teachers. Yet, recent research suggests that the impact of teachers' professional development on student achievement is limited (Huffman & Thomas, 2003). This is because the link between professional development and student achievement is complex and there are other possible factors that can influence the relationship (Huffman & Thomas, 2003). Loucks-Horsley and Matsumoto's (1999) research on teachers' professional development in mathematics and science revealed that high quality professional development should lead to improved teacher learning, which in turn, would lead to improved student achievement. However, even well-educated and confident teachers struggle to teach science, and they have difficulty applying strategies that they would like to use in the classroom (Appleton, 2003; Appleton & Kindt, 1999; Dickinson, 1997; Loughran, 1994).

Teachers' confidence and interest in science teaching determine how often they teach science, and how he/she teaches science. On the other hand, teachers' interest in science teaching is also affected by system priorities, and it is not just a personal view. Timetable problems (official time allocation to science) and other curriculum priorities also have a negative impact upon their teaching and resulting in subjects like science being dropped. All these reasons suggest that in schools there is no systematic support for teachers to teach science other than teacher's own extra efforts to include science in their daily routine (Appleton & Kindt, 1999).

Teachers who do teach science in kindergarten or first-grade can select from any number of different teaching strategies. Different theoretical perspectives suggest various ideas about children's development and how they learn science and other curricular content (Bowman, 1998). One commonly accepted approach draws on constructivist learning theories or *constructivism.* Social constructivists view learning as an active process where learners should learn to discover principles, concepts and facts for themselves, hence the importance of encouraging exploration, thinking, and hypothesizing (Brown et al.1989; Ackerman 1996). The Constructivist approach suggests that with appropriate materials and a social environment, children have the capacity to make their own discoveries and construct knowledge. This approach not only relies on children acquiring information for themselves, but it also requires creating a new understanding (Lind, 1999 & Ramos, 1999).

As indicated in the traditional proverb "I hear and I forget. I see and I remember. I do and I understand" (Croft, 2000, p. 219) children learn through direct experiences. By interacting with their environment children develop their own ideas which they use to make sense of the world around them. According to a constructivist view of learning, during science learning children use their existing ideas to interpret new information. The subsequent learning occurs as a result of students' reconstructed ideas (Palmer, 2003). Moreover, a varied social network can have different impacts on each child's cognitive development (Pellegrini, 2001; Teale, 1982).

"Constructivism is the view that knowledge of the world comes about through an individual's experience of it" (Driscoll, 2000, p.376). When learners attempt to make sense of their experiences, their knowledge is constructed. Classroom teaching approaches based on a constructivist theory of learning include problem solving, reasoning, critical thinking, and active and reflective use of knowledge. In order to extend and refine new knowledge the learner must activate prior knowledge and combine it with new ones (Moussiaux & Norman, n.d.). According to Siegler (1983), while children construct new knowledge, their previous concept knowledge influences how they acquire additional information. By embedding learning in a complex, realistic, and relevant environment, providing social negotiation as an integral part of learning, supporting multiple perspectives and using multiple modes of representation, encouraging ownership in learning, and nurturing self-awareness of the knowledge construction process, a constructivist approach enhances the ability to have a broad range of knowledge in every aspect of life. In addition, a constructivist approach also supports the process of learning in a sociomoral atmosphere in which respect for others is continually practiced (Driscoll; DeVries & Zan, 1994).

While a constructivist theory of learning can serve as a guide for selecting appropriate teaching strategies that enhance learning opportunities, it is well known that there are other variables that can influence children's science learning. These include child level variables, such as gender and race, and family level variables such as family type, maternal education level, and socio-economic status. Arguably, these variables are related to students' performance in the area of science learning.

National tests consistently report on the underachievement of minority students in the areas of science and mathematics (National Commission on Mathematics and Science, 2000; National Research Council, 1996). The National Assessment of Educational Progress (NAEP) science assessment tests in the fourth, eighth, and twelfth grades, suggest that African –American, Hispanic, and low-income European-American students lag behind other students. These students also tend to take fewer science courses and their enjoyment of science tends to decrease as they progress through school (Fryer & Levitt, 2004; National Science Foundation, 2005; Osborne, Simon, & Collins, 2003; Tenenbaum, Rappolt-Schlichtmann, & Zanger, 2004; Yager & Yager, 1985). This is of concern because student's enjoyment and motivation have been connected to their achievement in science by Welch, Walberg, and Fraser (1986). As a result of being from low-income families, these children also often receive inappropriate classroom instruction, information, and tests (Tenenbaum, Rappolt-Schlichtmann, & Zanger, 2004; Welch, Walberg, & Fraser, 1986). To increase student's science enjoyment hands-on, real world, activities should be integrated into the curriculum. This is so that children can become actively involved and, in turn, enjoy their learning (Harbeman, 1991; Tenenbaum, Rappolt-Schlichtmann, & Zanger, 2004).

Gender is another factor that can influence children's participation and achievement in science. Most studies (e.g., Adamson, Foster, Roark, & Reed, 1998; Becker, 1989; Fleming & Malone, 1983; Osborne, Simon, & Collins, 2003; Steinkamp & Maehr, 1985) show that gender difference in science achievement favors males. Typically, young children naturally explore and investigate, and learn from the world around them. Children at a young age, however, show a preference for different types of activities and play props. It is well known, for example, that wooden blocks are preferred by boys whereas dolls or housekeeping activities are chosen more often by girls. It is noteworthy that this gender related tendency is evident at a young age, and that it occurs before any significant academic achievement differences between girls and boys.

While in the early years of childhood same gender peer groups have powerful social influence on their preferences, later in their lives children's social relationships with adults (including teachers, parents, and advisers) can have an effect on their academic choices (Adamson, Foster, Roark, & Reed, 1998; Maccoby, 1990). There is no doubt that in late adolescence science is a highly gendered activity. There is however some uncertainty as to how and when this gender differentiation begins. More importantly is that the development and later manifestation of gender differences in academic interest and in science achievement has not been as thoroughly investigated by using valid and reliable longitudinal data.

Research studies have shown that children's scientific thinking can be shaped and supported by their parents. When children engage in activities with their parents in everyday, nonobligatory activities, they explore for longer periods of time, and they tend to be more focused (Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001; Ramsey & Fowler, 2004). The research literature shows that parents' involvement in children's schooling has various positive effects on children's learning. This involvement not only leads to more positive student attitude and behavior, but it also has the potential of improving children's academic achievement. However, in addition to parents' willingness to be involved in their children's schooling, there are other parental factors that could effect their participation in both positive and negative ways. These include family configuration (family type, SES) and the parents own educational background (Jones & White, 2000). According to Lee and Burkam (2002), a family's socioeconomic status is strongly related to children's cognitive skills, and generally children from higher socioeconomic status families begin school with higher reading and mathematics abilities. Such results are supported by the work of Bickel, Zigmond, and Strayhorn (1991) who note that children from high socioeconomic status families outperform children from low socioeconomic status families.

Purpose and Significance

This study attempted to determine how often science is taught in the early grades as well as the science topics taught in these grades. A related purpose of the study was to determine the relationship between science teaching and students' science achievement. In doing so, the analyses took into consideration the influence of gender, socioeconomic status (SES), and race/ethnicity on children's academic performance in science. By using the ECLS-K kindergarten and first-grade data files, children's science *item response theory scores* (*IRT)* were examined to measure the relationship between children's early science experiences in classrooms and their achievement on the "General Knowledge Assessment Battery". The *General Knowledge Assessment Battery* consists of items that measure children's knowledge in the natural sciences and social studies. "The science domain measures two broad classes of science competencies: (1) conceptual understanding of scientific facts, and (2) skills and abilities to form questions about natural world, to answer such questions on the basis of the tools and the evidence collected, to communicate answers and to explain how the answers were obtained" (NCES, 2002, p. 2-7). The test battery includes both natural science and social studies. The assessment domain of natural science and knowledge, however, is too diverse and the items are insufficiently ranked or graded to permit the formation of a set of proficiency levels. Therefore, in addition to the *IRT scores* from the *General Knowledge Assessment Battery*, in this study an indirect assessment of children's scores was used: *Academic Rating Scale Scores (ARS)*. The general knowledge section of the ARS scores includes teachers' ratings of each child's skills in social studies (three items) and science (three items) (NCES, 2002). Again, this study was conducted to define the current skill levels, knowledge, and behaviors of children in kindergarten and first-grade based on teachers' past observations and experiences with them (NCES, 2002).

By employing appropriate statistical analyses, the data from Early Childhood Longitudinal Study-Kindergarten class of 1998-99 (ECLS-K) was used to expand on the body of knowledge about young children's science development in kindergarten and first-grade. Beginning with kindergarten, the ECLS-K, conducted by the National Center for Educational Statistics (NCES), focuses on children's early school experiences. Using multisource and multi-method data collection methods the ECLS-K collected data form children, parents, and teachers (NCES, 2002, p. 1-1). The NCES study followed a nationally representative cohort of children from kindergarten through fifth grade and it included a total of 21,260 children from across the United States who were assessed both directly and indirectly. This study, therefore, aimed to better describe and understand children's science learning in the early grades by using appropriate sample weights.

Since, the ECLS-K is a national data set, the results that are generalizable to the United States population of kindergarten children, teachers, and schools that offered kindergarten programs in the 1998-99 school year. The findings should help inform early childhood teachers and administrators by identifying gaps in science teaching in the early grades. Such information is needed so that policy makers can direct resources toward improving science education in early childhood.

The study was guided by the following research questions:

1. How often is science taught in Kindergarten?
2. What science topics are taught in Kindergarten?
3. Are there differences in students' science scores, as measured by the direct (IRT) and indirect (ARS) assessment batteries in kindergarten and first-grade, by children's exposure to science activities and skills?
4. Does the relationship between the frequencies and types of science practices and children's science knowledge, as measured by the direct (IRT) and indirect (ARS) assessment batteries differ by children's gender, ethnicity, and socioeconomic status?

5. What is the longitudinal effect of science teaching and learning on kindergarten students' science achievement as measured by the direct (IRT) and indirect (ARS) assessment batteries?

6. Does the growth of children's science knowledge during the kindergarten year vary by children's gender, ethnicity, and SES?

Operational Definitions of the Terms

Item Response Theory Scores (IRT scores). IRT scores can compensate for the possibility of low ability student guessing several difficult items correctly. Scores reflect what the child would have achieved if all of the items had been administered. "IRT uses the pattern of right, wrong, and omitted responses to the items actually administered in a test and the difficulty, discriminating ability, and 'guess-ability' of each item to place each child on a continuous ability scale" (NCES, 2001. p. 3-2). Additionally, IRT scores allows researcher to measure gain scores in achievement over time (NCES, 2001).

Academic Rating Scores (ARS scores). The Academic Rating Scores (ARS) measure teachers' evaluations of students' academic achievement in general knowledge domain. Based on the teachers' past observations and experience with the child, ARS items aim to ascertain the current skill levels, knowledge, and behaviors of the child by using a five-point rating scale from "Not Yet", "Beginning", "In Progress", "Intermediate" to "Proficient". The teacher coded an item as N/A if the skill, knowledge, or behavior had not been introduced into classroom yet.

General knowledge & skills growth. General knowledge and skills achievement was the outcome variable of interest which is measured at three time points in the study; two times in kindergarten and one time in first-grade. The general knowledge assessment included questions designed to measure both social studies and science basic skills.

Hierarchical Linear Modeling (HLM). The HLM models allow researchers to look at various questions by exploring some empirical results that might otherwise have gone undetected. Since, behavioral and social science areas have a nested structure, for instance, repeated observations nested within persons/students and persons/students may be nested within organizations/classrooms. Furthermore, the organizational units/classrooms themselves may be nested within communities/schools, within states, and even within countries. Therefore, with HLM analyses we can pose questions/hypotheses about relations occurring at each level and across levels and also assess the amount of variation at each level (Raudenbush & Bryk, 2002).

CHAPTER II

LITERATURE REVIEW

A review of relevant literature and empirical research is presented in this chapter. The first section discusses what science really means in early childhood settings. Then, the next section provides an overview of science teaching at the kindergarten level by analyzing relevant studies that have explored young children's concept development about living things, health, physical, and earth sciences. The third section discusses theories developed by researchers, as they relate to constructivism and science learning and understanding. Next, the fourth section analyzes the potential influences on science learning (i.e., effects of home and school characteristics on young children's achievement). Additionally, this section discusses socio-demographic factors (e.g., SES, gender and ethnicity) that potentially influence young children's science learning and their conceptual understanding. In the fifth section empirical study results on young children's science achievement are discussed. Included are relevant theoretical and research reviews about the effect of child centered activities on children's learning and conceptual understanding, information about the frequency of science instruction in the early grades, the time that is devoted to teaching science in early childhood, and the science equipment and science areas in kindergarten classrooms. Finally, a summary is provided as well as relevant conclusions.

Theoretical Background

What is Science?

According to Chaillẻ and Britain (2003), science "…involves experimentation, creativity, and problem solving, all of which come into play as children try to understand the world" (p. 14) in early childhood settings. Science is a body of knowledge about the world around us, and the overall goal of science is to explain and describe phenomena in the natural world. Children's scientific experiences involve constant interaction between the known and the unknown (Fredericks & Cheesebrough, 1993). By accumulating knowledge from different sources such as, forming concepts about their natural world, human use of natural resources and the impact of this use on society, young children construct important ideas when they use the skills of science (Martin, Sexton, & Gerlovich, 2001). The body of science knowledge includes facts gathered, generalizations, and a set of principles that can be used to make predictions (Abruscato, 2004). In mathematics and science knowledge, concepts are developed through the use of processes and skills that children use as they think about their observations, reflects on their experiences and problem solve. In turn, this leads to an understanding of the nature of scientific inquiry (Charleswoth & Lind, 1999; Ebenezer & Connor, 1998; Good, 1977; Seefeldt & Barbour, 1998).

Mathematics and science process skills help children expand their learning through experience. Given relevant and appropriate experiences, these skills help children discover meaningful information, and gather knowledge within and beyond the mathematics and science classrooms (Martin et al., 1997). These skills can be grouped into eight categories of the thinking skills and processes necessary to learn mathematics and science.

Observing. Observing is the most basic process of science. When children observe they obtain information by using their senses such as, smell, sight, sound, touch, and/or taste. This process skill helps them to receive information about the world around them. Gaining the ability to make careful observations is the main foundation for making inferences or hypotheses that can be tested by further observations. Furthermore, providing opportunities to observe shape, size, color, texture, and other observable properties, provide children with information that they can use to solve problems (Abruscato, 2000; Charleswoth & Lind, 1999).

Comparing. When children develop skills in observation, they naturally begin to compare and contrast objects to identify similarities, differences, and interrelationships among them. The skill of comparing enhances children's observational skills and it is the first step toward classifying (Charleswoth & Lind, 1999).

Classifying. Classifying is another basic skill and it is the root of all understanding (Charleswoth & Lind, 1999). When children classify, they group and sort real objects (Charleswoth & Lind, 1999; Ebenezer & Connor, 1998). For example, children can classify objects in the following ways:

- Seeds by size, shape, or means of travel
- Insects by type, with or without wings
- Pictures of animals as wild, domestic, or living in a zoo
- Properties of objects – hard, smooth, soft, large, rough, bright, fat, thin, wide, narrow, shiny, sticky, loud, hot, and cold.
- Toys as wheel toys, wind-up toys, or toys to build with (Seefeldt & Barbour, 1998, p. 489-490).

Measuring. Measuring begins early in the preschool or elementary grades, and it requires comparing things to a standard. In the upper elementary grades, children are expected to measure with accuracy and to use various measuring devices. For young children, however, measuring will involve using nonstandard units such as a handful of rice or a couple of beans when creating their collage. In developing this skill children learn to measure length, area, volume, mass, temperature, force, and speed (Abruscato, 2000; Charleswoth & Lind, 1999; Ebenezer & Connor, 1998).

Communicating. Communication is not only important in human endeavors, but also in all scientific work. In early childhood science inquiries, communication refers to the skill of describing an experience. Written and oral descriptions such as pictures, dioramas, maps, journal, and reports would help young children communicate clearly. To be meaningful for others, the communication process requires that information be collected, arranged, and presented in a way that helps others understand the meaning being presented (Abruscato, 2000; Charleswoth & Lind, 1999).

Inferring. Before they make inferences, children make a series of observations, categorize them, and then try to give them some meaning. Inferring requires that children use prior knowledge and, by examining the observed data, suggest relationships between objects and events. It differs from predicting because predicting involves something that might happen in the future. On the other hand, inferences are based on judgments and evaluations. The inferring process is not suitable for young children because it mostly requires them to infer something that they have not yet seen, because it cannot be observed directly (Abruscato, 2000; Charleswoth & Lind, 1999; Ebenezer & Connor, 1998; Seefeldt & Barbour, 1998).

Predicting. The skill of predicting entails having children make a statement about what they expect to happen in the future. Prior knowledge, interpretation of observations, measurements, and inferring relationships between observed variables all play an important role in making a reasonable prediction (Charleswoth & Lind, 1999; Ebenezer & Connor, 1998).

Hypothesizing and Controlling Variables = Investigation. This process skill includes integrated skills that involve students' capabilities to think at a higher level. "These skills consist of identifying and controlling variables, defining operationally, forming hypotheses, experimenting, interpreting data, forming models making graphs, and investigating" (Martin et al., 1997, p. 20-21).

For young children, then, science is defined as a set of skills that are used to learn about the world, to interpret events, and to solve problems. This, however, does not mean that science is content free. Science is also defined as a body of knowledge. Typically, school science curricula define the science knowledge that children should learn at different grade levels. In recent years, professional organizations such as the American Association for the Advancement of Science (AAAS) have developed standards and expectations for early childhood science. Thus, there are national guidelines for science content in kindergarten, first-, and second-grade.

Science Content in Early Childhood

When it comes to children's understanding of science topics, most research studies have focused on middle and secondary students' understanding of scientific phenomena, and research on young children's science thinking is somewhat limited (Bar, 1989; Bell, 1985; Christidou & Hatzinikita, 2006). Research into children's learning in science suggests that early science explorations offer the potential for addressing and modifying children's ideas before they reach secondary school (Harlen, 2001). Yet, researchers and science educators differ in their interpretation of children's thinking. Goswami and Brown

(1989) for example suggested that children of pre-school age have prerequisite domain-specific knowledge, and that they can reason as well as children in higher grades, and/or even adolescents. Balanced programs that give attention to process and experience are necessary at the primary level in order to develop inquiry skills that lead to improved conceptual understanding (Adey & Shayer, 1993; Harlen, 2001; White, 1993).

Findings from recent studies (e.g., Aram & Bradsaw, 2001; Barman, Barman, Cox, Newhouse, & Goldston, 2000; Barman, Stein, Barman, & McNair, 2003; Krnel, Glazar, & Watson, 2003; Stovall & Nesbit, 2003) suggest that children's scientific exploration of how they classify objects or animals can provide a clearer picture of their cognitive level and growth. Consequently, it is important for teachers to find ways to access their students' prior knowledge before starting a new unit, and before they can teach a science concept in a developmentally appropriate manner.

To make teachers' task less overwhelming, the American Association for the Advancement of Science and the National Science Education Standards have defined the science content that should be taught to young children (Allen, 2006; "Sciencing" and Young Children, 2003). In doing so, they established a set of standards that specify the science that children grades K-4 should learn. These include the following three key areas:

- Life & Health science: characteristics and life cycles of organisms and their environments; personal health, body systems/functions, nutrition,
- Physical science: properties, position, and motion of objects; light, heat, electricity, and magnetism,
- Earth science: properties of earth materials, objects in sky, and changes in earth and sky (National Research Council, 1996).

Despite these clear guidelines, recent trends and reports on science in the early grades suggest that science content is limited in certain areas. In addition, there is some evidence that some topics are explored more often than others (AAAS, 1999). For instance, studies that have focused on children's learning outcomes in science typically involve life and health science (Bar, 1989; Barman, Barman, Cox, Newhouse, & Goldston, 2000; Barker, 1995; Bell, 1995; Christidou & Hatzinikita, 2005; Haslam & Treagust, 1987; Mintzes & Arnaudin, 1984; Smith & Anderson, 1984; Stavy, Eisen, & Yaakobi, 1987;

Stepans, 1985; Tunnicliffe & Reiss, 2000). In contrast, there is some reason to believe that earth/space and physical science are not addressed as often by early childhood teachers (Bar & Galili, 1994; Bar & Travis, 1991; Christidou and Hatzinikita, 2006; Rahayu & Tytler, 1999; Tytler, 2000). Research findings on children's understanding of the various categories of science knowledge are discussed in the following section.

Life and Health Science

Life science content includes the exploration of the senses, of living things and non-living things, life cycles, body systems, and ecology (Allen, 2006; "Sciencing" and Young Children, 2003; Worth & Grollman, 2003). By investigating the things around them, as well as investigating themselves, children begin to pose questions about living and non-living things – what they look like, how they live, and how they change.

Children's explanations of natural phenomena provide powerful insights about their developing understanding of causality. Explanations help children to go beyond simple observation of events to the causal relations connecting them. This is necessary for understanding scientific principles taught in school. By exploring causality of familiar objects, children can become proficient in causal thinking (Carey, 1985; Christidou & Hatzinikita, 2005; Metz, 1991; Wolfinger, 1982).

Although, a considerable amount of research has focused on different dimensions of school children's understanding of plant growth, they mainly refer to middle and secondary school students (Bar, 1989; Barker, 1995; Bell, 1995; Christidou & Hatzinikita, 2005; Haslam & Treagust, 1987; Stavy, Eisen, & Yaakobi, 1987). Christidou and Hatzinikita's (2005) study was one of the few studies conducted in early childhood settings. In this study, the researchers interviewed 60 children from public schools to explore their reasoning about plant growth and rain. Their findings suggested that young children are capable of handling naturalistic explanations in the case of plant growth because plant growth involves objects (the plant, and its parts, water, etc.) that children experience through direct access and manipulations. In contrast, other studies suggest that students' understandings of plants and what plants need to grow are often limited (Barker, 1995; Barman, Stein, Barman, & McNair, 2003; Barman, Stein, McNair, & Barman, 2006; Smith & Anderson, 1984; Stepans, 1985; Tunnicliffe & Reiss, 2000). Children in grades

K-2, for example, did not appear to make a connection between plants needing air and water for food production. As an alternative, they thought that the plant needed air for *breathing* and water for *drinking* much like humans and animals (Barman, Stein, McNair, & Barman, 2006). This lack of awareness of plant life and forest features is also observed in first-grade students (Strommen, 1995). It seems therefore that young children develop alternative conceptions (misconceptions) about plant growth. Thus, children need a range of rich experiences with plants and plant growth so that they can develop scientifically accurate understanding of the relevant concepts (Krantz & Barrow, 2006). Although students in kindergarten to grade four should understand that plants have basic needs that include air, water, nutrients, and light (National Research Council, 1996) results of different studies show that kindergarten students need help to visualize plants as living things (Barman, Stein, Barman, & McNair, 2003).

The distinction between living and non-living things is a critical component of early childhood science, and a prerequisite for children's biological learning and understanding. Young children, however, seem to have difficulties with this concept (Osaki & Samiroden, 1990; Venville, 2004). Children, who are able to recognize the meaning of *life* as biologists do, seem to have an appropriate level of cognitive understanding that allow them to develop new concepts and beliefs. Most science curricula include topics about living things, even in the very early years of schooling. This content in early childhood science is considered foundational knowledge that can expand children's understanding throughout elementary and secondary school (Venville, 2004). Findings from previous studies suggest that children initially fail to recognize plants as living things because plants display changes too slowly to be observed in natural contexts (Opfer, 2002; Opfer & Siegler, 2004).

Children's understanding of causality has been investigated by examining their vitalistic reasoning of life, the human body and death. In a recent study, Slaughter and Lyons (2003) interviewed sixty preschool children between ages of 3 and 5 to assess their knowledge of (1) human body function and (2) death. The results indicated that young children who spontaneously appealed to vitalistic concepts in reasoning about human body functioning were also more sophisticated in their understanding of death. Overall results also showed that the acquisition of a vitalistic causal-exploratory framework serves to structure children's concepts and facilities learning in the domain of biology (Slaughter & Lyons, 2003).

Carey (1985) claimed that ''young children know the relation between food and various processes and states of affairs—growing, being strong, being healthy, not dying, without any awareness of physiological mechanisms involved''(p. 45). Many studies have used structured interviews to find out what types of food children choose, and their understanding of nutrients, as well as the reasons why they eat food. The findings show that children below the age of seven have problems when they are asked to group foods based on their own classification. Yet, even four-year-olds can categorize foods when they are given food items rather than pictures to group. Providing explanations of the functions of specific nutrients in the body seemed to be difficult for children (Toyama, 2000; Turner, 1997). It follows that teaching biology in kindergarten, or in the lower elementary grades, is important in order to support children's already acquired form of autonomous biological knowledge (Hatano & Inagaki, 1997; Teixeira, 2000).

A related area of science content in the category of living things is the study of different types of animals. Although the word or concept of *animal* is used extensively in the lives of children, different studies suggest that young children have difficulty identifying animals such as, insects and mammals (Barman, Barman, Cox, Newhouse, & Goldston, 2000; Mintzes & Arnaudin, 1984). Barman et al. (2000) found that although K-2 students correctly identified more types of organisms (e.g. bird, frog, lizard, fish, spider, and snake) than older students, they believed that humans are not part of the animal kingdom. This shows that young children's (age 7 and younger) understanding of organisms tend to be based on perceptual and behavioral features because they focus on the size and shape of organisms as a means for identifying an organism (Shepardson, 2002).

Physical Science

One of the physical science content standards for grades K-4 is the states of matter. According to the National Education Standards "most students will have difficulty with the generalization that many substances can exist as either a liquid or a solid. K-4 students do not understand that water exist as a gas when it boils or evaporates; they are more likely to think that water disappears or goes into the sky. Despite that limitation, students can conduct simple investigations with heating and evaporation that develop inquiry skills and familiarize them with the phenomena" (National Research Council, 1996, p. 126)

Several researchers have studied the development of students' ideas about changes of state of water (evaporation, condensation, boiling, and melting). Most of these studies, however, have been conducted with secondary students (Bar & Galili, 1994; Osborne & Cosgrove, 1983; Tytler, 2000; Johnson, 1998). During the past two decades, few science education researchers have focused on primary school children's views and opinions about the state of water (Bar & Galili, 1994; Bar & Travis, 1991; Rahayu & Tytler, 1999; Tytler, 2000). By investigating primary children's views, Bar and Travis (1991) identified a growing confidence over the 6-13 year age range, with the relationship between water and vapor, and the existence of vapor in air. However, their work was questioned by Johnson (1998), who argues that the authors did not take children's language into account to describe changes, and their interchangeable usage of words like *vapor*, *mist*, *steam*, *gas*, and *air*. According to Johnson (1998) students have to learn the particle concept before learning the concept of evaporation. This is also supported by findings from other studies, in that while kindergarteners and second-grade students are able to perceive the phenomena involving changes of state, they are unable to express conceptions related to the changes of the state and the conditions under which the state the changes (Paik, Kim, Cho, & Park, 2004).

Results of these studies show the importance of children's active learning in science by having the opportunity to explore and observe. Children construct concepts about objects by acting on them, by observing what they can be used for, and by seeing what happens to them when an action is performed (Krnel, Watson, & Glazar, 2005). Therefore, children's ideas should be the starting point for teaching and learning in schools (Osborne & Cosgrove, 1983; Taiwo, Ray, Motswiri, & Masene, 1999; Tytler & Peterson, 2003, 2005; Varelas, Pappas, & Rife, 2006). Unless teachers identify children's views and design their teaching accordingly to enhance their ideas, children are not going to give up an idea (misconceptions) (Dove, Everett, & Preece, 1999; Hewson, 1981; Osborne & Cosgrove, 1983).

Krnel, Watson, and Glazar (2003) investigated the development of the concept of matter in children aged 3-13 by asking them to classify objects and matter. The results indicated that children were capable of learning to distinguish between the intensive properties that characterize matter and the extensive properties that characterize objects. Young children (age 3 to age 7) learn this by observing and interacting with objects and substances around them (Driver & Easley, 1978; Krnel, Watson, & Glazar, 2003, 2005). This helps them to build up more elaborated schema, which form the basis of concept development (Krnel, Watson, & Glazar, 2003, 2005; Mariani & Ogborn, 1990).

A limited number of studies have explored young children's understanding of light, time, speed, floating/sinking, and mechanical stability. The results of these studies indicated that although young children's content knowledge increased with different activities, generally they could not judge whether an object would sink or float, and they were unable to think of velocity and time before the age of 6 years. On the other hand, when abstract concepts of physical science are introduced to children in the early ages, these concepts can deeply interest young children, and they can foster lasting positive attitudes toward science (Cross & Mehegan, 1988; Long, 2001; Segal, 1997; Tenenbaum, Pappolt-Schlichtmann, & Zanger, 2004). When children become familiar with certain aspects of science phenomena at a young age, they are more likely start to seeing the multidimensional manner of objects or situations, and they produce new ways of looking at the phenomena (Havu-Nuutinen, 2005). Moreover, appropriately structured activities, with appropriate guidance by the teacher, are more effective than simple participation in the same activities (Hadzigeorgiou, 2002).

Earth and Space Science

Previous research on young children's understanding of natural phenomena such as, rain, clouds, the sun, moon, day, and night is also limited. Researchers conclude that children come into the classroom with an existing understanding of these phenomena (Borghi, De Ambrosis, Massara, Grossi, & Zoppi, 1988; Christidou & Hatzinikita, 2006; Henriques, 2002; Robbins, 2005; Stepans & Kuehn, 1985).

Borghi, De Ambrosis, Massara, Grossi, and Zoppi (1988) investigated young children's understanding of the physically complex problem of air and its properties. This was done by verifying whether participation in physical experiments, together with social interaction (with adults and class-mates), could help children's development of causal knowledge. They concluded that "a sequence of appropriate experiments, carried out with simple and easily handled materials, can lead to better thought structure through the acquisition of new variables and their progressive integration to one another" (p. 188). This view is also supported by Robbins (2005) who believes that children's science thinking is embedded within socio-cultural contexts, including the guidance of others, and the integration of certain mental and cultural tools.

In a recent study with preschool children, Christidou and Hatzinikita (2006) classified children's explanations of rain formation. The results indicated that children mostly used non-naturalistic explanations which include teleological (events occur in order to serve specific purposes e.g., 'it rains in order for plants to be watered and grow') and metaphysical (supernatural powers i.e., God or God-like entity) explanations. This suggests that while educators design scientific activities for young children, they should take into account the types and characteristics of children's explanations (Christidou & Hatzinikita, 2006; Stepans & Kuehn, 1985).

Children's daily experiences provide information that supports the development of their own mental models of astronomical phenomena (Kikas, 1998). However, their understanding cannot be developed simply through a process of direct observation and individual construction (Nobes, Moore, Martin, Clifford, Butterworth, Panagiotaki, & Siegal, 2003). Contemporary theories of astronomy differ from children's naïve models that are based on their own experiences and usage of language (Kikas, 1998; Vosniadou and Brewer (1992).

Vosniadou and Brewer (1992) studied first-, 3rd-, and 5th- grade children's conceptual knowledge about the shape of the earth. The results showed that most children have inconsistent ideas about the earth's shape, and they have difficulty understanding that the earth is spherical. Children's thinking is strongly influenced by observations of the local environment, and these observations are subsequently organized into coherent mental models. Children's concepts about the earth's shape were also investigated in a study by Hayes, Goodhew, Heit, and Gillan (2003). As in Vosniadou and Brewer's (1992) study, Hayes' (2003) results suggest that there is coherent structure within children's beliefs about the earth's shape, and that such beliefs represent their coherent mental models. In contrast, Nobes and colleagues (2003), when investigating young children's understanding of the earth, found no evidence that young children's knowledge is organized into mental models. According to their findings, children's knowledge of the earth is fragmented. "Fragments of knowledge appear to be acquired independently from one another, at different rates according to their content and to the linguistic ability of the child" (Nobes et al., 2003, p. 84).

The fact that national organizations have defined science content and standards for the early grades is particularly useful for teachers. It is also beneficial that researchers have examined young children's understanding of various science topics. Consideration of the teaching of science in kindergarten and in the primary grades can not be complete without understanding how young children learn science. The following section draws on various theories of cognitive development to examine how young children learn science.

How Do Children Learn Science?

The science teaching and learning standards (National Research Council, 1996, 2000) suggest that students cannot achieve high levels of performance without access to a rich array of learning materials and work spaces that offer hands-on and minds-on experiences. To achieve excellence, a more student-centered program is essential, as opposed the traditional format of lecture, text, and demonstration. Moreover, the standards assert that active learning must involve interaction with others (American Association for the Advancement of Science, 1993; National Research Council, 1996). This sociocultural perspective of learning is explained and supported by findings from research on social constructivism (Bruner, 1985; Kikas, 1998; Von Secker & Lissitz, 1999; Vygotsky, 1978).

The roots of constructivism date back to the time of Socrates. He asked his students direct questions so that they would realize weakness in their thinking. The works of Jean Piaget and John Dewey provides a theoretical framework for the constructivist approach in early childhood education programs. Dewey believed that education should be grounded in real experience. Other scholars and educators such as L. S. Vygotsky, David Ausebel, Jerome Bruner, C. Kamii, and R. DeVries added new perspectives to Piaget's and Dewey's works. While Vygotsky emphasized the importance of social relationships and interactions between the child and the world of others, Kamii and DeVries focused on the nature of the child's thinking and implications for effective classroom practice (Thirteen Ed. Online, n.d.).

Constructivism is a well recognized theoretical perspective on "knowing" and "learning" and it highlights the significance of the individual learner's prior knowledge in subsequent learning (Ausubel, 1968; Driver & Bell, 1986). This means that constructivism emphasizes the importance of each child's active construction of knowledge through the interplay of prior learning and newer learning (Yager, 1995). Thus, according to a constructivist perspective, young learners construct and reconstruct their own meaning for ideas about how the world works (Good, Wandersee, & St. Julien, 1993). Then, as social learners, children actively construct meaning, and their learning is embedded within social contexts (Tudge & Rogoff, 1989).

The theory of constructivism is derived from the contributions of several theorists, including Piaget, Vygotsyky, and Bruner. The theories developed by these individuals, as they relate to constructivism and science learning and understanding, are discussed in the following section.

Jean Piaget (1896 – 1980)

Piaget's theory of cognitive development contributed to the constructivist theory of learning. His primary interest was in knowing how the child comes to know his/her world. Piaget's view is called constructivism because of his belief that knowledge acquisition is a process of continuous self-construction. In other words, knowledge is external to children and they can discover/construct all knowledge about the world through their own activity by discovering concepts from previous experiences and through mental constructions. That is, children construct their own system of knowledge and their intellectual development controls other aspects of their development – emotional, social, and moral. (Berk, 2000; Driscoll, 2000; Gagnon & Collay, 2001).

Piaget considered three types of organization of thinking and reasoning that is crucial to cognitive development: assimilation, accommodation, and equilibration (Driscoll, 2000; Thomas, 2000). Assimilation is a "…process of thinking in or understanding events of the world by matching the perceived features of those events to one's existing schemes" (Thomas, 2000, p. 251). When a child is assimilating an object she/he gives one or several meanings to it. The term accommodation is used to identify the process of changing existing schemes to permit the assimilation of events that otherwise would be beyond a child's understanding (Thomas, 2000). Equilibration is the mix of both assimilation and accommodation that characterizes a child's transition from one stage of development to the next (Driscoll, 2000). Piaget also notes that there are four causal factors that determine how a child acquires his/her particular schemes: heredity (internal maturation), physical experience with objects, social transmission (education), and equilibrium (a balance among the other three) (Thomas, 2000).

The concept of cognitive development was central to Piaget's theory and he thought that children think and reason differently during different periods of their lives. Piaget categorized these differences into four primary development (intellectual) stages: sensorimotor, preoperational, concrete operational, and formal operational. These stages are predictable, and there is a relationship between children's logical thinking abilities and their maturation and development.

In the sensorimotor stage (0-2 years) the child's intelligence develops through his/her motor interactions with his/her environment. It is during this stage that play and imitation first appear (Aram & Bradshaw, 2001; Berk, 2000; Goffin & Wilson, 2001; Seefeldt & Barbour, 1998). By the end of this period children will have developed the concept of *object permanence*. This means that they realize that even though an object is out of sight, objects still exist (Charlesworth & Lind, 1999).

Children in the preoperational stage (3-7 years) are able to make mental representations of unseen objects, but they cannot use deductive reasoning. The cognitive structure during the concrete operational stage (8-11 years) is logical, but it depends upon concrete referents. The children can decenter and reverse their thinking, and though they can master logical problems one by one (horizontally), they cannot yet think abstractly. Then when children are in the formal operational period, they are able to engage in abstract thinking (Berk, 2000; Goffin & Wilson, 2001; Seefeldt & Barbour, 1998).

Piaget's cognitive development stages have been used as the basis for designing curricula that provides a starting point for educators to decide which science concepts are appropriate for students at various grade levels. The stages of development can act as a guideline for educators to determine the importance of children's development levels, and the content of science curricula. To ensure children's understanding of science, educators should match the science concepts to children's intellectual levels. Within science curricula that are based on a constructivist theory of learning, students can make sense of their environment through exploration, experimentation, and discussion. The use of manipulatives can help to create a supportive environment in which children can work (Bliss, 1995; Howe, 1996). According to Ebenezer and Connor (1998), "the child centered, hands-on approach; the discovery approach; and active learning are popular strategies acknowledging Piaget's principle of spontaneous knowledge construction" (p. 38).

In addition to the developmental stages, Piaget also described three types of knowledge that in reality are interdependent: physical knowledge, logico-mathematical knowledge, and social knowledge. Opportunities to experiment with the world include consideration of "physical knowledge" and learning derived from interaction with objects. It also includes both the properties of objects (their shape, size, textures, color, and odor) and knowledge about how objects react to different actions on them (they roll, sink, slide, dry up). Physical knowledge can be constructed by acting on objects (feeling, tasting, smelling, seeing and hearing them) by children. Well-developed physical knowledge helps children to be able to establish relationships (comparing, classifying, and ordering). Social knowledge is culture-specific and it is derived from interaction with people. On the other hand, logico- mathematical knowledge is abstract, and children invent or construct this kind of knowledge by developing relationships with physical and social knowledge (DeVries, Zan, Hildabrandt, Edmiaston, & Sales, 2002; Driscoll, 2000; Goffin & Wison, 2001; Kamii & DeVries, 1978; Smith, 1987).

Lev Vygotsky (1896 – 1934)

Lev S. Vygotsky, the Russian psychologist and philosopher, believed that an individual's development depends on the interaction of biological and maturational, environmental, and social factors. Vygotskian theory, often referred to as a "Socio-Cultural

Theory”, is a general framework for understanding learning and teaching. When the child becomes capable of mental representation through language, he/she moves from the natural line of development to the social line with higher cognitive processes. According to Vygotsky, when children are constructing their knowledge they control their own developmental process within a specific social context, and within this developmental process, language plays a central role. Social context plays an important role in children’s development because it is critical for the acquisition of mental processes. Mental processes not only occur internally, but they are also supported by an exchange among several people. At this point children’s social environments begin to play an important role. When the child internalizes a meaning, the interpersonal activity has been transformed into an intrapersonal one. Cooperative dialogues with more skilled peers and adults help the child to enrich his/her own potential developmental level. Vygotsky called the difference between the child’s actual developmental level and potential developmental level as the “Zone of Proximal Development” (ZPD). In the zone of proximal development, the role of education is to provide experiences that challenge the child, but can be managed with adult and more competent peer guidance (Berk, 2000; Berk & Winsler, 1995; Bodrova & Leong, 1996; Driscoll, 2000; Seefeldt & Barbour, 1998).

Jerome Bruner

The contributions of Jerome Bruner also support a constructivist view of learning. Bruner’s work significantly influenced the teaching of science in elementary schools. According to Bruner, education starts with a student’s interest and some basic knowledge (Hopkins, 1981; Thirteen Ed. Online, n.d.). “Learners’ ability to reflect on their own learning is key to the iterative process of constructing knowledge” (Aram & Bradshaw, 2001, p. 29). The student, by integrating his/her own existing knowledge and experience, formulates hypotheses, constructs new ideas, and selects information to construct new knowledge – the process of thinking (Driscoll, 2000; Hopkins, 1981; Thirteen Ed. Online, n.d.). This process also supports the need for active involvement in research, which at all levels calls for a more hands-on, inquiry based approach. Such an approach is considered a viable activity for solving problems and for science education (Berk, 2000; Berk & Winsler, 1995; Bodrova & Leong, 1996; Briscoe & Wells, 2002; Driscoll, 2000; Seefeldt

& Barbour, 1998). In using this approach the teacher has two essential roles: (1) providing opportunities for individuals to engage socially in talk and activity about shared problems and tasks and (2) leading students to conventional science ideas and serving as an expert to mediate social discourse (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Von Secker & Lissitz, 1999).

While the theories on children's cognitive development and constructivism guide our understanding of how children learn science, it is evident that there are many other influences on children's scientific understanding. If we are to understand how children learn science, and how science should be taught in the early grades, it is necessary to consider the various influences on children science learning.

Influences on Science Learning

Active Learning in Well Developed Environments

Due to increased recognition of the crucial importance of children's early experiences, there is a growing demand for early childhood services (Lind, 1999; Katz, 1997). The importance of children's early experiences is well documented (Davies & Ward, 2003; Harlen, 2001; Ravanis, 2004), and most educators agree that these early experiences influence children's functioning in school, as well as their functioning as adults. In quality early childhood programs, learning environments are arranged to provide young children with experiences that allow them to develop and learn to their maximum potential (Bredekamp & Copple, 1997; Getswicki, 1999, Harlen, 2001).

Within most early childhood programs children are provided a broad range of experiences. Typically, these are designed to further children's development in the social, emotional, cognitive, and physical domains. Most, kindergarten and primary-grade classes focus on children's learning in the cognitive domains, and therefore they emphasize learning traditional school subjects such as reading, mathematics, social studies, and science. The practical and "hands on" nature of science mean that it is a learning area that is particularly suitable and appropriate for young children. In other words, early childhood science can provide children with quality experiences that can further their cognitive development.

According to the National Science Education Standards, during the early years science is based on children's natural curiosity (Charlesworth & Lind, 1999; National Research Council, 1994). Moreover, science in early childhood is both a process of thinking and of gaining knowledge about the nature of the world (Charlesworth & Lind, 1999; National Research Council, 1994). Since children are naturally interested in learning about the everyday world, establishing a classroom environment that engages children's attention and participation is a critical first step that supports their development and learning (French, 2004). Additionally, the importance and influence of the classroom learning environment on the process of education has been addressed by several researchers (Aldridge, Fraser, & Huang, 1999; Alridge, Laugksch, Seopa, &Fraser, 2006; Anderson, Lin, Treagust, Ross, & Yore, 2007).

The science education standards also define learning as an active process that occurs when students are given an opportunity to construct understanding through empirical investigations and social interaction with others (National Science Council, 1996). Recent study results have highlighted the importance of social and motivational influences of students' engagement during learning activities (Ash, 2004; Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001; Hall & Schaverien, 2001; Solomon, 2003). Providing students with opportunities to conduct scientific investigations should lead to increases in science achievement for all students, and a decrease in achievement gaps among more and less advantaged groups of students (Von Secker & Lissitz, 1999). For example, results from many studies suggest that teachers who frequently use standards-based teaching practices, that include scientific inquiry, positively influence urban, African-American students' science achievement and attitudes. Thus, inquiry learning seems to be positively related to students' science achievement. Multiple performance opportunities and noncompetitive learning environment as well as student responsibility for, and choice of, learning activities also lead to higher achievement, interest and confidence (Kahle, Meece, & Scantlebury, 2000; Lee, Deaktor, Hart, Cuevas, & Enders, 2005; Mao & Chang, 1998; Stohr-Hunt, 1996; Teel, Debruin-Parecki, & Covington, 1998; Von Secker & Lissitz, 1999).

For classroom-based scientific inquiry to be successful it is important to organize the learning environment and use interest or learning centers appropriately. Well-organized learning centers can be used for a wide variety of purposes including making science learning more relevant for children. Learning centers can serve two functions. First, teachers can observe children's behaviors and test certain ideas about what needs to be included to support children's learning. Second, these areas allow children to interact with others and with objects, by using different materials and sharing ideas and feelings (Branscombe, Castle, Dorsey, Surbeck, & Taylor, 2003). Such learning centers can provide opportunities for children to use scientific knowledge in real-life independent activities. Learning centers should be designed to enhance the learning of concepts, skills, themes, or topics. Different instruments, tools, and materials should be available in learning centers so that they can be easily accessed by children. In turn, children are provided with limitless possibilities for exploration and engaging in a host of hands-on experiences with science (Fredericks & Cheesebrough, 1993; Siraj-Blatchford & MacLeod-Brudenell, 1999). It follows that teachers should prepare by selecting materials that encourage in-depth science explorations (Worth & Grollman, 2003).

While inquiry-based science learning experiences are important, young children should not be hurried into conducting controlled experiments too early. This is because they do not have the cognitive ability to understand how two or more causal variables interact (Elkind, 1989). Self-discovery can be rewarding and motivating, yet it is necessary to provide a certain amount of direction from outside, especially for children in grades K-8 (Butts, 1963). It is known that students' classroom experiences have an effect on their perceptions and attitudes toward science (Kyle, 1985). The most successful learning centers in science are those in which teachers and students have an equal say in their design and activities. This means that children should be provided opportunities to be involved in, and given a voice, in determining how those activities are planned and accomplished. Consequently, children will have a sense of responsibility for their own learning.

Effects of the Home and School

The research literature has revealed that multiple variables of home, school, and individual students are related to student learning. To understand the differences in achievement among children, one must take into account factors such as family status, school climate, learning activities, and student's own characteristics (National Center for Education Statistic, 1995). This framework is presented in figure 2.1.

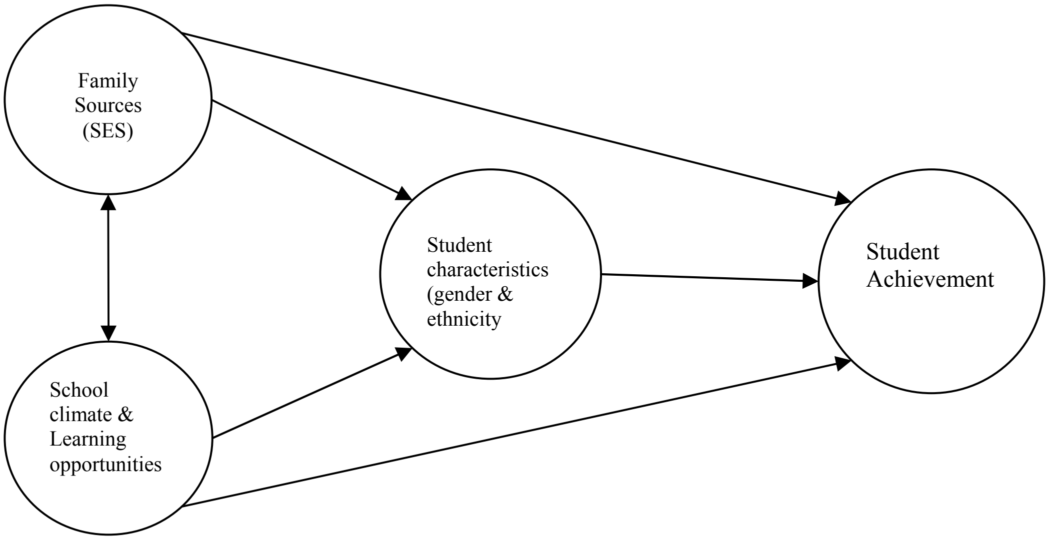

Figure: Influences in Science Learning

According to Von Secker (2004) parent education, home environments, and instructional opportunities can compensate for risks of academic failure that are associated with low socioeconomic status, minority status, or gender. Garmezy (1983) points out that home learning experiences and quality external support systems, such as schools, can lead to academic success. Numerous study results show that the oldest and most persistent explanations for achievement differences are quality of home environments, such as parent education, and a rich collection of literacy-based materials (Garmezy, 1983). Yet, "for many children the combination of a constructionist paradigm and transformational interactions is available at home, but not at school" (Segal, 1997, p. 6) because the child at home leads the communication process, but at school, the process is teacher-driven (Segal, 1997).

Equally important, because of its influence on children’s academic achievement, is the external support system (schools). Guided by the National Science Education Standards (National Research Council, 1996) schools are provided with specific guidelines for science instruction. These standards suggest that science teaching should include experiences in which students engage in hands-on inquiry in their classrooms (Von Secker, 2004). This approach is not without its critics, however. Rodriguez (1997), for example, criticizes the science education standards because they emphasize the importance of promoting science achievement for all students, regardless of demographic status. Furthermore, Rodriguez (1997) claims that science education reforms are “… not directly addressing the ethnic, socioeconomic, gender, and theoretical issues which influence the teaching and learning of science in today’s schools” (p.19). Although the instructional emphases presented in the national standards explain discrepancies in student achievement, it is still somewhat unclear how the interaction of children’s learning experiences and student background variables influence science achievement (Von Secker, 2004).

Gender and Ethnicity Issues

Arguably, the lack of female students engaging in science learning and science related occupations is a serious concern. For example, females are underrepresented in science related employment in the United States (Blake 1993; Ebenezer & Connor, 1998). Although females have made great strides in recent years in catching up in science participation, science still tends to be a male dominated discipline (Blake 1993; Ebenezer & Connor, 1998; Geiger & Litwiller, 2005; Johnston, 1996). Gender differences in science have been linked to many problems, such as teacher behaviors toward girls, stereotype (as a male activity), community/parental expectations, and sexism in textbooks (Blake 1993; Ebenezer & Connor, 1998; Geiger & Litwiller, 2005; Johnston, 1996). Allen (1995) suggests that teachers should evaluate themselves using the following questions to compensate for gender bias in classroom teaching:

- Are female students given an equal amount of attention from the teacher?
- Do female students feel comfortable enough to ask *many* questions of the teacher?
- Is the class tension level comfortable and the discipline under control?

- Do female students appear fearful of being embarrassed when asking a question, or is a teacher or are male students sarcastic toward the answers given by female students? (Allen, 1995, p. 33).

Gender differences in attitudes have been found at all levels of development, and attitude toward science is thought to occur early (Johnston, 1996). There have been numerous investigations of gender and science during late childhood and adolescence (Becker, 1989; Fleming & Malone, 1983; Kahle, 2004). Typically, the results of these studies show that science achievement favors males (Adamson, Foster, Roark, & Reed, 1998; Greenfield, 1996; Kahle, 2004). Achievement differences in science learning are evident by the end of the high school. While there may be many reasons for such differences, it is believed that a lack of motivation and cultural differences can lead to underachievement in science among girls. To date, however, our understanding of the influences of these noncognitive variables during childhood is limited (Adamson, Foster, Roark, & Reed, 1998; Becker, 1989; Kahle & Lakes, 1983).

Children's race/ethnicity and the socioeconomic levels of their families should also be taken into account when comparing their achievement levels in science. This is because science achievement tends to vary in direction and degree across various racial/ethnic groups. From the nation's point of view, gaps in achievement of different ethnic groups would subsequently affect the quality and quantity of human resources in this country, because minority populations have been growing at a much faster rate than the mainstream population (National Center for Education Statistics, 1995). Moreover, American schools show a lack of excellence in fostering the learning of mathematics and science. The problem is primarily apparent in the schooling of ethnic minority students, such as African Americans, Hispanics, and American Indians, who show lower educational attainment, grades, graduation rates, and school persistence (California State Department of Education, 1986; Sue & Okazaki, 1990; Spence, 1985).

In a related study, Pollard (1993) concluded that gender differences in active problem solving favored African American girls in comparison to African American boys. A follow-up study found that African American students' academic self-concept were related more closely to actual academic achievement than to gender. Kahle, Meece, and

Scantlebury (2000) investigated factors that affect the achievement of urban, African American eighth graders achievement levels in science. They found that gender differences between boys and girls were complex, and they followed the same pattern: (1) African American girls out-performed the boys in science, (2) stronger positive relationship between attitudes and achievement in science for boys compared with girls, and (3) peer participation and home support were more positively correlated with achievement for African American girls than for boys.

Many studies have also documented that Asian American students do well in school with lower dropout rates, higher achievement scores, and higher college entrance rates than other ethnic groups (National Center for Education Statistics, 1993; Peng & Wright, 1994). The results of both Peng and Wright (1994) and Sue and Okazaki (1990) studies indicated that Asian American children's achievement is linked to their family structure, time spent doing homework, and to attending lessons outside of school. More importantly, Asian American parents had higher educational expectations for their children.

Studies of gender, ethnicity, and achievement in Asian and other Pacific Islander ethnic groups have yielded inconsistent results. For instance, some studies found that gender differences in mathematics achievement favored girls. In another study, conducted in China, there were consistent gender differences in children's mathematics and science achievement favoring boys. However, for Asian and Pacific Islander populations in the United States, there appears to be an advantage for females with respect to educational level and achievement (Greenfield, 1996). Greenfield's study (1996) also revealed that ethnicity had a greater impact than gender on science achievement, attitude and perceptions. According to the results, the differences reflected most favorably on Caucasian and Japanese Americans. In terms of gender differences it appeared that females' science achievement and attitudes frequently equaled those of males. It is clear that minority children fall behind others in science achievement. Understanding why these differences exist is critical for the well-being of individuals in society as well as for determining how to improve science education in this country.

Although different indicators such as socioeconomic status, race/ethnicity, and gender may have strong effects, and be highly predictive of science achievement, they should not be interpreted as conclusive since there are other risk factors that may produce negative effects on student learning. This means that individuals are not at risk for low science achievement simply because they are poor, female, or minority; rather, they are part of highly variable risk populations. The main problem is that researchers often forget to pay closer attention to substantial within-group heterogeneity that mostly accounts for most of the variance in science achievement (Von Secker, 2002, 2004).

Empirical Studies on Young Children's Science Achievement

The successful flight of the Soviet Sputnik in 1957 alerted the Nation that revolution in education in the United States is needed (Abramson, 2007; Stohr-Hunt, 1996). Consequently, nationwide reform efforts in the teaching science and mathematics were started. By questioning the effectiveness of science instruction, leaders, teachers, researchers and administrators became concerned about the future of science instruction in America. As a result, they developed new standards and goals for the teaching of science and mathematics in schools (Jorgenson & Vanosdall, 2002; Stohr-Hunt, 1996). In the years that followed, several studies were conducted by researchers to examine children's progress in science, and to evaluate the effectiveness of various science teaching and learning programs.

One widely accepted goal of science education is to extend students' knowledge of the world with the activities that give rise to that knowledge (Abruscato, 2004; Zimmerman, 2005). Researchers who investigate the development of children's scientific knowledge often focus on the acquisition of two main types of knowledge: domain-specific and domain-general strategies. While domain-specific knowledge includes studying the development of the scientific reasoning (concepts) that children and adults develop by investigating phenomena, domain-general studies focus on problem-solving skills applied to the context of a scientific investigation (e.g., Carey, 1985; Hatano & Inagaki, 1997; Klahr & Dunbar, 1988; Klahr, Fay, & Dunbar, 1993; Mahoney & DeMonbreun, 1977; Vosniadou & Brewer, 1992; Zimmerman, 2005). Few research studies have been conducted to quantify the impact of child-centered activities, frequency of science instructions, the time that is devoted to teach, the science equipment, and science areas in the early grades on children's science achievement. In most studies, researchers tend to focus on upper elementary students' or/and higher grade students' achievement, and children from kindergarten and in early elementary grades are typically excluded (e.g., House, 2005; Huffman & Thomas, 2003; Johnson, Kahle, & Fargo, 2006; Schroeder, Scott, Tolson, Huang, & Lee, 2007; Stohr-Hunt, 1996; Von Secker & Lissitz, 1999; Wu & Huang, 2007).

This is surprising because the Glenn Report highlighted our children's lack of ability to respond the challenges of 21st century. This important report stated that the teaching pool in mathematics and science is inadequate to meet our current needs. To improve American students' mathematics and science performance there is a need for better mathematics and science teaching across all grades, including the early grades (i.e., kindergarten to third-grade). The report also stated that with hands-on approaches to learning, in which students participate and exercise in real-life situations, children not only learn but they also gain skills to help them become responsible their own learning (National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

In conclusion, this review of the literature suggest that there is a need for studies that specifically investigate the effects of child-centered activities, frequency of science instructions, the time that is devoted to teach, the science equipment, and science areas in the early grades on children's science achievement. Moreover, such studies should be based on various measures of student learning in science, including formal and informal assessment scales. Since the ECLS-K data was released in 2000, numerous studies and reports have been published that explored children's reading and mathematics achievement. Few studies, if any of these studies, have examined the longitudinal relationship between children's early science experiences and their science achievement. To improve science teaching, the strength of associations between classroom-based instruction and science achievement, with reference to issues of equity for students who are risk of low of under-achievement, need further examination (Von Secker & Lissitz, 1999).

Summary and Conclusion

The No Child Left Behind (NCLB) Act of 2001 calls for the reform of education by suggesting partnership of every sector of society with schools to increase young children's achievement in mathematics, reading, and science. The NCLB also emphasizes the importance of establishing academic standards in science teaching by using research-based teaching methods, and regularly measuring students' academic progress. (Schroeder, Scott, Tolson, Huang, & Lee, 2007; The Facts about Science Achievement, n.d.).

To compare American children's performance in mathematics, science, and reading with other nations, the United States participates in two international assessments (i.e., Trends in International Mathematics and Science Study: TIMSS and the Program for International Student Assessment: PISA). When the results of these studies are compared with the National Assessment of Educational Progress (NAEP), also known as the Nation's Report Card, they reveal little or no change in U.S. students' science achievement over the last decade (Schroeder et al., 2007). These results call for better science teaching in schools. Several strategies have been proposed to improve students' science performance (e.g., establishing an ongoing system to improve the quality of mathematics and science teaching in grades in K-2, increasing the number of teachers, improving the quality of their preparation, and improving the working environment for mathematics and science teachers) (National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

The National Science Education Standards also provide specific guidelines for science instruction for K-12 classrooms to help teachers to organize their instructions and activities to assist young children to achieve their high levels of performance (National Research Council, 1996). Learning materials, work spaces and child-centered science instruction that offer hands-on and minds-on experiences are recommended so that young children's sense of responsibility for their own leaning can be enhanced, and also so that the achievement gap between more and less advantaged groups of children can be decreased (Kyle, 1985; Von Secker & Lissitz, 1999).

Young children start to learn about the everyday world from birth. Early science learning experiences play an important role, not only in fostering young children's experiences in science, but also in supporting their later success (Lind, 1999; Katz, 1997). By using the process skills, children in early grades experience different areas of science (i.e., life and health science, physical science, and earth science) (Gallenstein, 2003). Teachers can support the development of the process skills in young children by using constructivist teaching strategies. Under the rubric of "constructivism", educators and researchers have recommended many strategies for teaching science in the early grades (Jones, Lake, Lin, 2008).

Constructivism offers an explanation of how children learn science and the theory implies approaches that support student's learning. Such approaches emphasize the importance of young children's active learning by providing opportunities to investigate materials and objects so that they reconstruct their own meaning for ideas about how the world works (Good, Wandersee, & St. Julien, 1993; Marin, Benarroch, & Gomez, 2000; Newman, & Griffin, et al., 1989; Yager, 2000). In science education, the constructivist approach plays an important role in understanding how children's learning takes place, and how children play an active role in constructing new knowledge. Piaget, Vygotsky, and Bruner have explained the development of concepts based on a constructivist approach. According to these theorists, children are individual explorers, making their own discoveries, and constructing knowledge. By interacting with materials and other people, they develop their science skills, and ideas about scientific phenomena (Lind, 1999).

Piaget believed that knowledge is external to the individual and therefore the child can discover/construct all knowledge about the world through his or her own activity and a process of assimilation/accommodation (Aram & Bradshaw, 2001; Berk, 2000; Goffin & Wilson, 2001; Seefeldt & Barbour, 1998). In contrast, Vygotsky emphasized the influence of social, cultural, and historical factors on children's cognitive development. According to Vygotsky, the social context plays an important role in children's development because it is critical for the acquisition of mental processes. Cooperative dialogues with more skilled peers and adults help the child to enrich his or her own potential development level (Berk, 2000; Berk & Winsler, 1995; Bodrova & Leong, 1996; Driscoll, 2000; Seefeldt & Barbour, 1998). Bruner, like Piaget, emphasizes the students' active role in the learning process, and in the child's cognitive development. Bruner believed that one of the most important outcomes of cognitive development is thinking. In addition, Bruner maintains that discovery learning provides experiences that help children discover science concepts for themselves (Driscoll, 2000; Hopkins, 1981; Thirteen Ed. Online, n.d).

Constructivist teaching methods cannot be applied without having a rich array of learning materials and work spaces that offer hands-on and minds-on experiences. Beyond constructivist theories of learning and related teaching strategies, it is evident that there are many other influences on children's scientific understanding. In well-developed environments, science learning will result in higher achievement for all students (Von Secker & Lissitz, 1999). Results from many studies reveal that standard-based teaching practices with appropriate materials provide opportunities for children to use scientific knowledge in real-life independent activities (Fredericks & Cheesebrough, 1993; Siraj-Blatchford & MacLeod-Brudenell, 1999). These activities also affect children's perception and attitude toward science (Kyle, 1985).

Multiple variables of home, school and students' own characteristics are also potentially related to students' learning (National Center for Educational Statistics, 1995). Von Secker (2004) stated that the quality of home environments (e.g., parent education, home environments, and instructional opportunities available at home) can compensate for risks of under achievement associated with low socioeconomic status, minority status, and gender (Garmezy, 1983; Von Secker, 2004). Additionally, the lack of female involvement in science related employment shows that more effective classroom experiences should be provided to compensate for gender bias in classroom teaching (Blake, 1993; Ebenezer & Connor, 1998; Geiger & Litwiller, 2005; Johnson, 1996). Study results related to the relationship between children's ethnicity and their achievement have shown that motivational and cultural differences on gender differences can have an impact on children's achievement. However, influences of these noncognitive variables during childhood have yet to be fully understood (Adamson, Foster, Roark, & Reed, 1998; Becker, 1989; Kahle & Lakes, 1983).

In looking at the general literature discussing research in early childhood settings, it is evident that most of the studies examining children's concept development have been conducted by psychologists. The effects of the frequency of science activities in different science content areas, the time that is devoted to teaching science in early childhood, and the availability of science equipment and science areas in classroom have not been widely investigated. In particular, the longitudinal effects of these variables on student's learning in science have not been tested and compared using direct (item response theory scores) and indirect (academic rating scores) assessment batteries. It seems that science teaching and learning in early childhood settings has been neglected by researchers. This study attempted to fill this gap by investigating the status of science teaching and learning in Kindergarten and by estimating the effects of various teaching practices on children's science achievement in kindergarten and first-grade.

CHAPTER III

METHODOLOGY

This study examined young children’s science experiences in both kindergarten and first-grade, and the effects of these experiences on their academic performance in science. The study used data from the Early Childhood Longitudinal Study – Kindergarten Class of 1998-99 (ECLS-K) kindergarten and first-grade data files. First, this data was used to determine how often science was taught in kindergarten classes. Second, the data provided information concerning the science topics taught in kindergarten as well as information concerning instructional strategies and resources used in kindergarten classrooms. Next, the data was used to examine the relationship between science instruction and science achievement in kindergarten and first-grade. Two measures were used here. Children’s science item response theory (IRT) scores and the Academic Rating Scale (ARS) obtained from the “General Knowledge Assessment Battery” were used as measures of children’s achievement in science. “The General Knowledge Battery includes both natural science and social studies items. The general knowledge section of the ARS scores includes teachers’ ratings of each child’s skills in social studies (three items) and science (three items) (US Department of Education, 2002). The natural science assessment domain was considered too diverse, and the items are insufficiently ranked or graded to permit the formation of a set of proficiency levels.

The assessment data was then used to examine the relationship between science instruction (i.e., frequency of instruction, time) and students’ achievement in science. The analyses were designed in order to control for the effects of certain child-level variables (i.e., gender, race, and socio-economic status) as well as the cross-sectional and longitudinal effects of classroom science teaching practices.

Data used in the study came from the National Center for Educational Statistics (US Department of Education) Early Childhood Longitudinal Study Kindergarten Class of 1998 (ECLSK). The ECLS-K focused on children's early school experiences. Using multisource and multimethod data collection methods data was gathered from children, parents, and teachers (US Department of Education, 2002). Thus, the ECLS-K followed a nationally representative cohort of children from kindergarten through fifth-grade. A total of 21,260 children from throughout the United States were assessed both directly and indirectly. Because of the sampling methods that were used in the ECLS-K, the current study employed appropriate sample weights. This was so that the findings could be generalized to the population of United States kindergarten students enrolled in public school during the 1998-99 academic year. Findings from this study should help identify gaps in science teaching in the early grades, and inform early childhood teachers and administrators about influences on young children's achievement in science. Such information is needed so educators and policy makers can direct sources toward improving science education in early childhood.

In this chapter, the methodology that was utilized in the study presented. First, a brief description of the ECLS-K data is provided including selection of participants, data collection procedures, preparation for data collection, administration of the direct child assessment instruments, and teacher and parent data collection methods. This is followed by a description of the measures that were utilized in the study. Finally, a full description of the analytical procedures used in the study is provided.

Description of the Data

Under the sponsorship of the U.S. Department of Education, the Early Childhood Longitudinal Study-Kindergarten Class of 1998-9 (ECLS-K) was developed by the National Center for Educational Statistics (US Department of Education). By focusing on children's early school experiences beginning with kindergarten, the ECLS-K collected data from a nationally representative sample of children from kindergarten through fifth grade. The ECLS-K includes data from more than 20,000 nationally representative children, a survey from one of each child's parents, 8,000 kindergarten and first-grade teachers, and the administrators of more than 1,000 schools. The main purpose of the data set was to produce a more accurate measure of different factors, such as the effects of preschool and elementary programs in which children participate, the services they receive, and children's cognitive skills and knowledge within and across different primary grades. In addition, the ECLS-K database provided measures of children's physical health and growth, social and emotional development as well as information about family background, and the educational equality of children's home environments (US Department of Education, 2001).

The ECLS-K can be used for both descriptive (children's status at entry into school, children's transition into school, and their progress through fifth grade) and analytic purposes (how a wide range of family, school, community, and individual variables affect children's early success in school, explore school readiness and the relationship between the kindergarten experience and later elementary school performance, and children's cognitive and academic growth as they more through elementary school). The major objectives and potential applications of the ECLS-K were as follows:

> (1) a study of achievement in the elementary years;
>
> (2) an assessment of the developmental status of the children in the United States at the start of their formal schooling and at key points during the elementary school years;
>
> (3) a cross-sectional study of the nature and quality of kindergarten programs in the United States; and
>
> (4) a study of the relationship family, preschool, and school experiences to children's developmental status at school entry and their progress during the kindergarten and early elementary school years (US Department of Education, 2001, p, 1-1).

The ECLS-K provides several unique advantages for researchers. First, the dataset enables researchers to use analytic techniques such as multilevel modeling to study how school and classroom factors affect the progress of individual children. In turn this approach allows educational policy analysts to adopt an ecological perspective on early childhood education. Of primary interest in the current study was exploring kindergarten and first-grade teachers' instructional strategies and the resources they use, and the students' early science experiences as measured by different classroom level variables such as frequency of various classroom science activities and science topics: plants and animals, dinosaurs and fossils, solar system and space, weather, temperature, water, sound, light, magnetism and electricity, hygiene etc. (US Department of Education, 2001).

Second, the longitudinal nature of the ECLS-K allows researchers to study how a child's cognitive, social, and emotional growth is jointly determined by interactions among child, family, teacher characteristics and school environments. This nationally representative large-scale database provides rich information on children's status at entry into kindergarten and their academic progress through fifth-grade. Hence, one of the strengths of the ECLS-K data is in its ability to generalize findings (Chapin, 2006; US Department of Education, 2001). In the current study, data from three waves of administration of the science achievement assessment measure (i.e., fall and spring of kindergarten and spring of the first-grade) were used.

Finally, the ECLS-K describes the diversity of kindergarten children and the programs they attend. The database includes information about both public and private kindergarten programs and the children who attend them. Additionally, the ECLS-K sample includes children from various minority groups, and present many possibilities for studying cultural and ethnic differences (e.g., educational differences, approaches of families, learning styles of children, and educational opportunities for children from different groups) (US Department of Education, 2001).

Sampling Design and Sample Weights

The Early Childhood Longitudinal Study-Kindergarten Class of 1998-99 (ECLS-K) used a nationwide representative sample of children attending kindergarten in 1998-99. This was done by employing a multistage probability sample design. The first stage of this process was to develop procedures of sampling units (PSUs). First, the 1990 county-level population data was used to frame PSUs and this contained 1,404 counties or groups of contiguous counties with a minimum 15,000 people. Because of the nature of the ECLS-K, the existing PSU frame was updated with 1994 population estimates of five-year-olds by race/ethnicity using data from the U.S. Census Bureau. To be eligible for selection in the study each PSU was required to have at least 320 five-year-old children. Each PSU in the frame that did not have at least 320 five-year-olds was collapsed with an adjacent PSU. Following application of these procedures, the final 1,335 PSUs were utilized and 100 PSUs were selected for the ECLS-K.

In the second stage of sampling, public and private kindergarten programs were selected using existing school universe files: the 1995-96 Common Core of Data (CCD) and the 1995-96 Private School Universe Survey (PSS). The school frame was freshened in the spring of 1998 in order to include newly opened schools, and schools that were in the CCD and PSS but did not offer kindergarten. The eligibility requirement for inclusion was a class of at least 24 kindergarteners for public schools, and 12 for private schools. This was done in order to obtain a sample that would be closer to a self-weighting sample of students and, thereby, achieve the minimum required sample size for Asian and Pacific Islanders (APIs) since this was the only subgroup that needed to be oversampled. Two independent sampling strata (1) API students (2) non-API students were formed within each school. Within each of these strata, the selection of public and private schools was systematic and the probability of selection proportional to the measure of size. APIs were the only group that needed to meet the sample size goals and so they were sampled at 2.5 to 3.0 times the rate of non-API students in schools. The final ECLS-K school frame included 914 public school records and 363 private school records (US Department of Education, 2001).

Once children's identification was completed, children's parent(s) or guardian(s) contact information was obtained to gain consent for the child assessment and for the parent interview. Additionally, a census of kindergarten teachers was taken at each school to link each child to his or her kindergarten teacher. During spring 1999, revisions and updates were made in terms of adding new teachers and child-teacher connections (US Department of Education, 2001).

The intent of Spring-first-grade data collection was to include every eligible child attending the school in which he or she had been sampled in fall- or spring-kindergarten. Unfortunately, due to high mobility and as a result of the high cost of collecting data for a child who transferred from school, fall-first-grade data collection was limited to a 30 percent subsample of 5,650 children. In order to recover the reduced sample size and unrepresentativeness of the sample, the spring-first-grade student sample was freshened to include first graders who had no chance of selection in the base year because they did not enroll in kindergarten in the United States. A random 50 percent subsample of base year sampled children and schools were flagged as follow-up for spring-first-grade. The final spring-first-grade sample included 18,084 children, excluding freshened students (US Department of Education, 2002).

Sample Weights

Since the ECLS-K used a multistage probability sample design, including equal probability systematic sampling for students other than APIs and a higher rate of probability sampling for APIs, not all schools, teachers, and children had an equal probability of selection. To adjust for the effects of nonresponse, and to compensate for differential probabilities, the ECLS-K data were weighted. Basically, application of weighting procedures provides representation of the sample to the population of kindergarten children, kindergarten teachers, and schools offering kindergarten programs. There are three essential questions that researchers should answer when choosing appropriate weights for their analyses: (1) Is the analysis concerned with one point in time or two? (2) What is the population of interest or unit of analysis (i.e. child, teacher or school)? (3) What instruments do the data to be used in the analysis come from? (US Department of Education, 2001, p. 4-11). In the current study the following weights were used:

> BYCW0: “child direct assessment data and child characteristics from both fall- and spring kindergarten, alone or in conjunction with any combination of a) a limited set of child characteristics (e.g. age, sex, race-ethnicity), b) fall- and/or spring-kindergarten teacher questionnaires A, B or C data, and c) data from the school administrator questionnaire or facilities checklist” (US Department of Education, 2001, p. 4-17).
>
> C2CW0: “spring-kindergarten direct child assessment data alone or in conjunction with any combination of a) a limited set of child characteristics (e.g. age, sex, race-ethnicity), b) any spring-kindergarten teacher questionnaire A, B or C data, and c)

data from the school administrator questionnaire or facilities checklist" (US Department of Education, 2001, p. 4-13).

C4CW0: "spring-first-grade direct child assessment data alone or in conjunction with any combination of a) a limited set of child characteristics (e.g. age, sex, race-ethnicity), b) any spring-first-grade teacher questionnaire A, B or C data, and c) data from the school administrator questionnaire or facilities checklist" (US Department of Education, 2002, p. 4-13).

The ECLS-K used a complex data design, and therefore, special statistical procedures were suggested for estimating the statistical significance of the estimates to overcome possible inflation in estimating the standard errors. By assuming that the data were collected with a simple random sample (SRS), the Statistical Program for the Social Sciences (SPSS) can be used to correct the standard errors with average root design effect (DEFT) (US Department of Education, 2001). On the other hand, these procedures do not apply to newer versions of Hierarchical Linear Modeling (HLM) software. Early versions of the HLM software used only the Huber-White robust standard errors. Later versions of HLM6 also have a model based approach that might be better with small numbers of level 2 units. Therefore, HLM does automatically correct the standard errors for the design weights (S. V. Raudenbush, personal communication, April 25, 2008).

Sample

ECLS-K participants were assessed in kindergarten, first-, third-, and fifth grade. "The primary sampling units (PSUs) were geographic areas consisting of counties or groups of counties. The second-stage units were schools within sampled PSUs. The third and final stage units were students within schools" (US Department of Education, 2001, p.4-1). After defining sample units, several data collection sources and methods were applied to obtain substantial information about the schools, teachers, and children: child direct assessments, parent interviews, self administered questionnaires for school or district administrators, principals, and teachers, student record abstracts, school facility checklist, and school records. Additionally, parent interviews were conducted through computer-assisted telephone/personal interviewing (CATI/CAPI) and child assessment was conducted using Computer-Assisted Personal Interviewing (CAPI).

Included in the current study were kindergarten and first-grade ECLS-K participants who were assessed in fall of 1998, spring of 1999, and spring of 2000. Three types of filtering procedures were used to select the subsample: (1) only first time kindergarteners who attend kindergarten in 1998-99; (2) children who repeated either kindergarten or first-grade were excluded from the study; and (3) children who had completed all of the assessments.

The resulting sample is close to a random sub-sample of 9,758 students who were enrolled in kindergarten classes in 687 public schools in the United States.

Procedures

Data Collection Procedures

Key educational organizations and associations representing parents, school administrators, teachers, and private religious and nonreligious schools were contacted for endorsement. After receiving the endorsement from state agencies or dioceses for a commitment to participate, letters were sent to the chief state school officer of each of the 41 states to explain the objectives of the study and data collection procedures. Having gained approvals at the state level district public and private school superintendents were contacted in order to obtain permission to contact schools. Then, beginning in March 1998, school administrators were contacted. Once permission was obtained from school administrators, two school visits by ECLS-K field staff were scheduled. The purpose of the preassessment visits was to obtain lists of names of kindergarten children and teachers. Furthermore, during the preassessment visits the sample of children was drawn, the cooperation of the teachers was secured, and parents' contact information was obtained. Then, having secured this information, parent information packets, including consent forms, were mailed, and questionnaires were distributed to the participating teachers and principals. Finally, necessary arrangements were made for collecting completed questionnaires and conducting the child assessments. During the second visit direct child the assessment procedures were completed (US Department of Education, 2001).

For fall kindergarten level data, three different training sessions were conducted to prepare field staff for data collection tasks: (1) for staff recruiting schools into the study, (2) for field supervisors, and (3) for assessors. Then for spring kindergarten level data training was provided for continuing staff as well as new staff. Most of the field staff were selected from among "retired teachers, former educators, people experienced in conducting assessments, or people experienced in working in schools or with school-age children" (US Department of Education, 2001, p. 5-4). During the training sessions all field staff received eight hours of home study training on the study design including areas such as, conducting the direct child assessment procedures, keyboard skills, and general interviewing techniques. Field supervisors were trained in supervision activities. Additionally, both field supervisors and assessors participated in training sessions on assessment activities and parent interviewing skills. A total of 112 field supervisors and 343 assessors were selected for the study and they all attended the training sessions. Field staff received in depth assessor training so that the direct child assessments would yield reliable results. The main purpose of the training was to follow "standardized procedures for administration of all assessment items as well as maintaining a neutral rapport with the sample children" (US Department of Education, 2001, p.5-5).

Conducting the direct child assessment. Fall kindergarten data collection began in September and ended in early December of 1998 (a 14-week period), and the spring kindergarten data were collected between March and June 1999. The other two waves of data collection were conducted between September and November 1999 for fall first-grade, and in 2000 from March to June for spring first-grade. The direct child assessment took place in a room which was set up by the assessors and supervisors. Typically this was in a school classroom or library. Each child was signed out of his or her classroom prior to the assessment and signed back into the classroom right after the assessment. Each assessment session lasted approximately 50 to 70 minutes.

Children who were identified as having a home language other than English (according to school records) were administered the Oral Language Development Scale (OLDS). Children who performed below the cut off score and whose primary home language was Spanish could be administered the Spanish version of the OLDS and some other direct cognitive measures. However, for the fall kindergarten wave of testing, the children who failed the OLDS were not administered direct child assessment because the general knowledge assessment battery (also the reading battery) was designed to be administered only in English. “As in spring kindergarten data collection, for children with a language other than English in the home, the child’s score on the oral language development scale (OLDS) administered in the prior round determined what path the child would follow in fall-first-grade” (US Department of Education, 2002, p. 5-6). Children who scored at or above the cut point in the previous OLDS assessment were automatically selected to take the direct child assessment in English, “children who scored below in the cut point in the OLDS in fall-kindergarten were administered the OLDS again in spring kindergarten and routed according to the new spring-kindergarten OLDS score” (US Department of Education, 2001, p. 5-26). The same procedure was applied in fall- and spring- for first-grade children participating in the study.

Conducting the parent interview. The ECLS-K parent interview was conducted by phone, and in person with parents who did not have a telephone. Typically, the respondent for the parent interview was the mother of the child. On some occasions, the responder could be a father, stepparent, adoptive parent, foster parent, or another relative or nonrelative guardian. The questionnaire was also translated into Spanish, Lakota, Hmong, and Chinese for parents who were not able to speak English. Assessors located parents by using the contact information obtained from the school. In both fall and spring of kindergarten, seven percent of the parents’ interviews were conducted in a language other than English. In the fall ninety-four and in the spring sixty-one percent of the non-English parent interviews were conducted in Spanish (US Department of Education, 2001; 2002).

Teacher data collection. Kindergarten fall teacher data was collected between September and December 1998. During the preassessment visits, the teacher questionnaires were distributed to kindergarten teachers to complete individual ratings for the sampled children in their classrooms. Participating teachers received an honorarium of five dollars for each child rating they completed (Teacher Questionnaire C). Then for the spring kindergarten and first-grade teacher data collections, teachers were reimbursed seven dollars for each of the child ratings they completed (US Department of Education, 2001; 2002).

Measures

The Early Childhood Longitudinal Study-Kindergarten Class of 1998-99 (ECLS-K) used several types of scores on various types of scales in order to describe children's cognitive and social development during the kindergarten year. These scores included a direct cognitive assessment, an academic rating scale (ARS), a psychomotor assessment, and a social skills rating scale (SRS).

Direct Cognitive Assessment

The direct cognitive assessment batteries consisted of three subject areas: reading, mathematics, and general knowledge. Children's cognitive skills were assessed in the fall and spring of kindergarten, and in the fall and spring of first-grade (the fall-first-grade data collection was limited to a 30 percent subsample of schools and unlike the base-year and spring-first-grade data collections, no teacher and other school questionnaires were administrated) (US Department of Education, 2001; 2002).

The direct cognitive assessment consisted of a set of two-stage assessments. In the first stage, children received a 12- to 20- item routing test, with a broad range of difficulty, in each subject area. According to their performance on the routing items, one of several alternative second-stage forms that contained items of appropriate difficulty for the level ability indicated by the routing items were administered. The reading and mathematics assessments had low, middle, and high difficulty second-stage options, while the general knowledge assessment had two second-stage alternatives. "The purpose of the two-stage design was to maximize the accuracy of measurement and reduce administration time by using the children's responses from the first stage to route the children to the appropriate level of difficulty in the second stage" (US Department of Education, 2002, p. 2-5). Scores for each subject area were computed only if at least ten questions were answered in the combined first and second stages. Children were not asked to write anything on paper or to explain their reasoning; rather they were instructed to point at the correct answer or to respond orally.

Direct cognitive assessment of general knowledge. The general knowledge assessment included both science and social studies material. The social studies items assessed the following areas: key events in American history, community resources, mapreading skills, different cultures, reasons for rules/laws/government, and geography. To measure children's science competencies two broad science items were used; (a) conceptual understanding of scientific facts and (b) skills and abilities to form questions about the natural world. The assessment questions drew on children's experiences with the environment by focusing on conceptual understanding, observing, and collecting data/classification, communication, ecology, the scientific method, and drawing/testing inferences in the context of questions based on life science and the physical sciences. Generally, the science domain included questions from the fields of earth, physical, and life sciences.

The General Knowledge Test items were the least described and most inaccessible part of the databases. Items were not released and combined into scores to eliminate item-level information. Therefore, the social studies and science items cannot be separated within the General Knowledge Test. Moreover, some of the test items are too complicated and cannot be counted in either the science or social studies category. The general knowledge assessment domain was too diverse and the items insufficiently ranked or graded to permit the information of a set of proficiency levels. Calculated scores represented each child's breadth and dept of understanding of the world around them. "This assessment captured information on children's conception and understanding of social, physical, and natural world and of their ability to draw inferences and comprehend implications. The skills children need to establish relationships between and among objects, events, or people and to make inferences and to comprehend the implications of verbal and pictorial concepts were also measured" (US Department of Education, 2001, p. 2-7).

On the direct cognitive assessment, there were five types of scores used to describe children's performance: "(1) number right scores and (2) item response theory (IRT) scores, which measure children's performance on a set of test questions with a broad range of difficulty; (3) standardized scores, which report children's performance relative to their peers; (4) criterion-referenced proficiency level and (5) proficiency probability scores, which evaluate children's performance with respect to subsets of test items that mark specific skills" (US Department of Education, 2001, p. 3-1).

In the current study, children's science achievement levels were assessed by using IRT scale scores. There are several advantages of using IRT scores rather than raw scores or T-scores. IRT scores can compensate for the possibility of low ability students guessing several hard items correctly. Scores reflect what the child would have achieved if all of the items had been administered. "IRT uses the pattern of right, wrong, and omitted responses to the items actually administered in a test and the difficulty, discriminating ability, and 'guess-ability' of each item to place each child on a continuous ability scale" (US Department of Education, 2001. p. 3-2). Additionally, IRT scoring enables researchers to measure longitudinal achievement gains over time (US Department of Education, 2001).

Appropriate reliability statistics for each type of score, for each subject area, and for each round was also provided. "For the IRT-based scores, the reliability of the overall ability estimate, theta, is based on the variance of repeated estimates of theta. These reliabilities, ranging from 0.88 to 0.97, apply to all of the scores derived from the theta estimate, namely, the IRT scale score, T-scores, and proficiency probabilities" (US Department of Education, 2001, p. 3-13; 2002, p. 3-15). Reliabilities in the general knowledge provided in Table 3.1 below.

Table 3.1
Reliability of the General Knowledge Assessment Instrument

Category	IRT-based scores (reliability of theta)		IRT-based scores (reliability of theta)	
	Fall-kindergarten	Spring-kindergarten	Fall-first-grade	Spring-First-grade
General Knowledge	.88	.89	.89	.89

Indirect Cognitive Assessment of General Knowledge

In addition to the direct cognitive assessment scales, the ECLS-K also includes "the academic rating scale (ARS)". The ARS was used to measure teachers' evaluations of students' academic achievement in the general knowledge domain. The ARS contains items that overlap and expand what is measured in the direct cognitive assessment. Although the direct and indirect cognitive assessment batteries include items that measure children's skills and behaviors within the same domain they are fundamentally different. This is because the direct assessment battery measures only the products of children's achievement, whereas the indirect assessment battery measures both the process and products of children's learning in school. The ARS also reflects a broader sampling of the most recent national curriculum standards and guidelines from early childhood professionals and researchers. The ARS, therefore provides a better understanding of not only the process of children's thinking, including the strategies they use to investigate a scientific phenomenon, but also the scope of curricular content in schools.

The ARS is based on the teachers' past observations and experiences with the child. For this instrument, teachers rate children's current skill levels, knowledge, and behaviors on a five-point rating scale as follows: "Not Yet", "Beginning", "In Progress", "Intermediate" and "Proficient". Teachers were required to code an item as N/A if the skill, knowledge, or behavior had not been introduced into classroom yet (Table 3.2). The general knowledge section of the ARS includes three items from the science domain (US Department of Education, 2001; 2002).

Table 3.2
ARS Response Scale

Not Yet:	Child has not yet demonstrated skill, knowledge, or behavior.
Beginning:	Child is just beginning to demonstrate skill, knowledge, or behavior but does so very inconsistently.
In progress:	Child demonstrates skill, knowledge, or behavior with some regularity but varies in level of competence.
Intermediate:	Child demonstrates skill, knowledge, or behavior with increasing regularity and average competence but is not completely proficient.
Proficient:	Child demonstrates skill, knowledge, or behavior completely and consistently.
N/A:	Not applicable: Skill, knowledge, or behavior has not been introduced in classroom setting.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), 2001.

Variables

Gender

The gender composite variable was derived from the parent interview data. If this information was either missing or different from the fall-kindergarten parent interview and spring-kindergarten parent interview, data from the field management system (FMS) was used.

Race/Ethnicity

For the purposes of this study the race/ethnicity composite that was constructed consisted of five categories: (1) White, non Hispanic (2) Black, or African American, non Hispanic (3) Hispanic (4) Asian, and (5) Other (which included Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children).

Socioeconomic Status (SES)

The socioeconomic scale (SES) variable was computed at the household level for the set of parents who completed the parent interview in the fall or spring. The following components were used for the creation the SES: Father/male guardian's education, mother/female guardian's education, father/male guardian's occupation, mother/female guardian's occupation, and household income. Not all parents responded to all of the questions, and therefore a hot deck imputation methodology was used to impute for missing values for all components of the SES. Basically, the value reported by a respondent for a particular item is given to similar person who failed to respond to that question. In this study, the continuous measure of family socioeconomic status (WKSESL) was used. The WKSESL variable ranged from -4.75 to 2.75 for the kindergarten year and -2.96 to 2.88 for the first year (US Department of Education, 2001; 2002).

Frequency of Science Instruction

Two variables were obtained from the teacher interview data the kindergarten level: A2OFTSCI and A2TXSCI. For this data teachers were asked "how often and how much time do children in your class(es) usually work on lessons or projects in [science] whether as a whole class, in small groups, or in individualized arrangements (A2OFTSCI)?" The responses were scaled from a low of one (*Never*) to a high of five (*Daily*). Thus, the scale corresponded to the five-point rating scale used to determine the frequency of science activities in the classroom. The second variable (A2TXSCI) was derived from teachers' answers to a question about the length of time of these science activities during a regular day in classrooms. This variable's value ranged from a low of 1 (*1 to 30 minutes a day*) to a high of 4 (*more than 90 minute a day*).

Science Equipment and Child-Selected Activities

Teachers were also asked to report information about children's involvement in child-selected science activities on a daily basis (A2CHCLDS). This variable ranged from a low of 1 (*no time*) to a high of 5 (*three hour or more*). Additionally, the frequency of children's use of science materials and resources (A2EQUIPM) and their use of measuring instruments (A2RULERS) in the classroom was rated on a six-point scale that ranged from zero (*not available*) to six (*daily*).

Science Topics

Teachers also reported on how much time they spent on various subject areas, including social studies and science. The kindergarten teachers' responded to questions about the nature of science topics taught, and the time they devoted to these science topics. Categories of science topics and activities include: ordering objects, sort into subgroups using rule, reading dimple graphs, simple data collection/graphing, use measuring instruments accurate, estimating quantities, the human body, plants & animals, dinosaurs & fossils, solar system & space, weather, know & measure temperature, water, sound, light, magnetism & electricity, machines & motors, tools & their uses, health/safety/nutrition/hygiene, scientific method.

Outcome Variables

There were two outcome variables of interest, both of which were measures of students' achievement in science. Item Response Theory (IRT) scores based on the full set of items in the General Knowledge Test scores were used. In the ECLS-K, IRT scores were computed in order to portray children's achievement on the direct cognitive assessment. IRT scores allow researchers to chart children's achievement gain over time because they reflect how many items they would have answered correctly had they been administered the entire battery of items. The second outcome variable was the Academic

Rating Scores (ARS). This measure was used to overlap and enhance the information gathered through the direct cognitive assessment.

Statistical Analyses

The sample employed in the current study included students who completed the general knowledge assessments in fall 1998 and spring 1999 of kindergarten, and spring 2000 of first-grade. Only first-time kindergarten students were included in the study. Students identified as learning disabled were excluded from the study. The data was restricted to the sample by including only students who remained in the same school across the base year and into first-grade.

The first two research questions (how often is science taught in Kindergarten? and what science topics are taught in Kindergarten?) were analyzed using descriptive analysis. The descriptive analyses included frequencies, means, minimum and maximum values, and standard deviations for the variables, such as gender, race/ethnicity, socioeconomic level, and science topics. Additionally, Pearson Product Correlation Moment correlations and mean comparisons along with effect sizes were provided. The effect sizes were calculated using Cohen's formula (Cohen, 1988) ($d = M_1 - M_2\sqrt{[(\sigma_1^2 + \sigma_2^2)/2]}$). Children's progress in science within and across kindergarten and first-grade was determined by using Hierarchical Linear Modeling (HLM) techniques. Hierarchical Linear Modeling (HLM, 6.06 version) was used to analyze research questions 3 through 6. HLM is useful when the data has a nested structure. Since students in this study are nested within classrooms, and classrooms are nested within schools, observations cannot be independent from each other (Raudenbush & Bryk, 2002). HLM provides a more reliable method for researchers to identify influences of different variables that would have an effect on outcome variables. Initial analyses included an estimation of the unconditional model. This was then followed by adding the student-level and school-level predictors. All variables that did not have a meaningful zero were grand mean centered.

Cross-Sectional Multilevel Analysis

Research questions 3 and 4 were investigated by using cross-sectional data analyses by way of two-level HLM modeling.

The research questions guiding this part of the study are as follows:

Question 3. Are there differences in students' science scores, as measured by the direct (IRT) and indirect (ARS) assessment batteries in kindergarten and first-grade, by children's exposure to science activities and skills?

Question 4. Does the relationship between the frequencies and types of science practices and children's science knowledge, as measured by the direct (IRT) and indirect (ARS) assessment batteries differ by children's gender, ethnicity, and socioeconomic status?

Four cross-sectional multilevel models were constructed and each model was specified by grade level for both outcome variables: general knowledge *Item Response Theory* (IRT) scores and *Academic Rating Scores* (ARS). Two-level hierarchical linear models are appropriate when there are two levels (e.g., students are nested within classrooms) (Raudenbush & Bryk, 2002). Modeling procedures were started with an unconditional model that included no independent variables at the student and school levels. A student model, with student level predictors in the first model, was followed by a school model with school level variables.

Longitudinal Data Analysis

In addition to the cross-sectional multilevel analysis, with a similar approach, research questions 5 and 6 were explored by using a three-level HLM growth modeling with Kindergarten data set.

Question 5. What is the longitudinal effect of science teaching and learning on kindergarten students' science achievement as measured by the direct (IRT) and indirect (ARS) assessment batteries?

Question 6. Does the growth of children's science knowledge during the kindergarten year vary by children's gender, ethnicity, and SES?

CHAPTER IV

RESULTS

This chapter presents results of the data analyses that explored young children's science experiences in kindergarten and the effects of these experiences on children's academic performance in science. Several child-level variables, namely; gender, race/ethnicity, and socioeconomic status, as well as school-level variables, namely; frequency of science instructions, time for science , frequency of child-selected activities, frequency of children's use of science equipment, and different science topics were included in the analyses. The following research questions guided the study:

1. How often is science taught in Kindergarten?
2. What science topics are taught in Kindergarten?
3. Are there differences in students' science scores, as measured by the direct (IRT) and indirect (ARS) assessment batteries in kindergarten and first-grade, by children's exposure to science activities and skills?
4. Does the relationship between the frequencies and types of science practices and children's science knowledge, as measured by the direct (IRT) and indirect (ARS) assessment batteries differ by children's gender, ethnicity, and socioeconomic status?
5. What is the longitudinal effect of science teaching and learning on kindergarten students' science achievement as measured by the direct (IRT) and indirect (ARS) assessment batteries?
6. Does the growth of children's science knowledge during the kindergarten year vary by children's gender, ethnicity, and SES?

The results are presented in three main sections: descriptive analyses of science instruction at the kindergarten level, cross-sectional Hierarchical Linear Modeling analyses of both the kindergarten and first-grade data, and longitudinal Hierarchical Linear Growth Modeling analyses of the kindergarten data. Both cross-sectional and longitudinal growth modeling analyses were repeated for both the IRT and ARS data.

In the first section, the results of the analyses that address the first two research questions' are reported. The results are displayed for the following areas: frequency of science instruction in kindergarten, daily science instruction, child-selected science activities, science equipment and measurement instrument use, and the different types or categories of science topics and activities.

The next two sections are organized as follows: First, descriptive statistics, including sample sizes, means, standard deviations, minimum and maximum values, IRT and ARS scores by gender, and correlations are reported. Here, the mean comparisons along with the effect sizes were calculated using Cohen's formula (Cohen, 1988). Next, the results of the cross-sectional HLM analyses are presented for each grade level, starting with the kindergarten analyses and then followed by the first-grade analyses. The results for each grade level include results for both the IRT and ARS outcome variables. The longitudinal HLM analyses also included kindergarten results for the IRT and ARS scores. Here, initial data analyses included estimation of the unconditional model before adding the student level and school level predictors. All variables that did not have a meaningful zero were grand mean centered. The analyses were all conducted using SPSS 16.0 and HLM (6.06) statistical software.

Descriptive Analyses of Science Instruction in Kindergarten Level

Descriptive analyses were conducted in order to describe the general picture of science instruction at the kindergarten level. The first series of analyses identified the frequency of science instruction in kindergarten level. According to the data only 18% of the teachers reported that they taught science on a daily basis. Furthermore, 48% of the kindergarten teachers reported that taught science 1 or 2 times a week, and 27% reported that they taught science 3 or 4 times a week. Table 4.1 presents the frequency of science instruction in kindergarten.

Table 4.1
Frequency of Science Instruction in Kindergarten

	Less than once a week	1-2 times a week	3-4 times a week	Daily	Total
How often Science	6.8	48.1	27.2	17.9	100.0

The kindergarten teachers were asked about the time they spent teaching science. In answering this question, 71% said that they taught science for less than 30 minutes a day. Approximately one fourth (26%) of the respondents reported that they taught science for between 30 and 60 minutes a day, and only 2.6% claimed that they taught science for more than one hour per day. The frequency of daily science instruction in kindergarten is reported in Table 4.2

Table 4.2
Frequency of Daily Science Instruction

	1-30 minutes a day	31-60 minutes a day	61-90 minutes a day	More than 90 minutes a day	Total
Time for Science	70.8	26.7	2.3	.3	100.0

The teachers also reported on how often they allowed their kindergarten students to engage in child selected science activities. The majority of the teachers noted that they allow their students participate in child-selected activities. The findings on the frequency of child selected activities are reported in Table 4.3. According to the kindergarten teachers, the students in their classes frequently use science and measuring equipment. Table 4.4 reports on the frequencies of children's use of science and measuring equipment.

Table 4.3
Frequency of Child-Selected Activities

	No time	Half hour or less	About one hour	About two hours	Three hours or more	Total
Child-Selected Activities	1.4	41.8	46.7	8.7	1.3	100.0

Table 4.4
Frequency of Children's Use of Science Equipment and Measuring Instrument

	Not Available	Never	Once a month or less	Two or three times a month	Once or twice a week	Three or four times a week	Daily
Frequency Use Science Equipment	3.3	1.8	16.5	26.9	24.4	11.8	15.3
Frequency Use Measuring Instruments	-	6.2	36.0	32.6	16.5	5.8	3.0

The next series of descriptive statistical analyses examined how often various science topics were taught in kindergarten. Table 4.5 includes the frequencies of teaching of various science topics and activities.

Table 4.5

Frequency of Different Types of Science Topics and Activities

	Taught at a higher grade level	Children should already know	One a month or less	2-3 times a month	1-2 times a week	3-4 times a week	Daily
Sort into subgroups using rule	1.9	1.0	7.0	26.8	34.5	18.6	10.2
Ordering objects	.5	1.1	9.3	31.5	35.0	14.7	8.0
Reading simple graphs	2.0	.3	11.1	29.6	27.3	10.3	19.4
Simple data collection/graphing	6.2	.1	21.2	33.7	21.1	6.8	10.9
Use measuring instruments accurate	17.8	.1	31.9	30.5	14.1	2.8	2.9
Estimating quantities	8.8	.0	24.2	30.0	23.8	6.0	7.1
Human body	12.4	.9	35.5	29.1	11.9	5.0	5.2
Plants and animals	.9	.3	25.9	39.2	19.6	8.6	5.5
Dinosaurs and fossils	32.1	.2	43.5	15.6	4.9	1.8	1.9
Solar system and space	39.6	.1	40.0	13.5	3.2	1.8	1.9
Weather (rainy, sunny)	.5	.4	8.0	8.2	8.6	8.6	65.7
Know and measure temperature	33.1	.2	25.7	13.3	7.5	4.5	15.7
Water	20.5	.1	46.2	20.8	7.3	2.2	2.8
Sound	33.9	.1	41.0	16.5	5.3	1.1	2.1
Light	39.5	.1	39.3	14.5	4.6	.7	1.4
Magnetism and electricity	43.0	.0	38.6	12.2	3.5	1.2	1.5
Machines and motors	62.1	.3	27.6	6.7	2.1	.2	.9
Tools and their uses	40.1	.3	39.1	12.8	4.3	1.3	2.1
Health/safety/nutrition/hygiene	.6	.4	18.3	23.3	16.9	10.5	30.0
Scientific method	47.8	-	26.9	14.7	6.2	2.3	2.1

According to the data, the most commonly taught science topics (i.e., on a daily basis) in kindergarten were “weather” (66%), “health/safety/nutrition/hygiene” (30%), and “reading simple graphs” (20%). In contrast, topics in physical science seemed to be avoided. For example, “machines/motors” was taught by only 1%, “light” by 1.4%, “magnetism/electricity” by 1.5%, and “solar system and space” and “dinosaurs and animals” by 1.9%. Surprisingly, only 5% of the teachers indicated that they taught science topics related to the human body on a daily basis, despite the fact that 30% taught “health/safety/nutrition/hygiene” on a daily basis.

A high percentage of kindergarten teachers believed that physical science topics should be taught at higher grades: ‘machines/motors’ 62%, ‘scientific method’ 47.8%, and ‘magnetism/electricity’ 43%. In contrast they reported teaching several topics on a regular basis (i.e., once a month or less): ‘water’ (46%), ‘dinosaurs/fossils’ (43.5%), ‘sound’ (41%), ‘solar system/space’ (40%), ‘light’ (39.3%), and ‘tools and their uses’ (39.1%). The findings suggest that teachers emphasize topics in the biological science and health at the expense of physical science topics.

Results of Two – Level Cross-Sectional Hierarchical Linear Modeling

Information about the sample size (N) and descriptive statistics for the variables of interest (student and school-level) are reported in Table 4.6. The Kindergarten data consisted of 9758 students nested within 687 schools. Children’s socioeconomic status scores ranged from -0.99 and 2.67 (Mean: 0.04, SD =0.67). The majority of the participants were Caucasian (60.2%) followed by African-American (14.9%), Hispanic (13.8%), others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) (6%), and Asian (5.1%). The mean of the science (IRT) score was 27.10 and the standard deviation (SD) was 7.58. The scores for IRT ranged from a low of 7.65 to a high of 48.44. The mean of the ARS science score was 3.62 and the standard deviation was 0.95. Here the scores ranged from a low of 1.00 to a high of 5.00.

Table 4.6

Descriptive Statistics for Kindergarten Level Science IRT & ARS Score Analysis

Variables	N	Mean	SD	Minimum	Maximum
		Level – 1			
Science (IRT)	9758	27.10	7.58	7.65	48.44
Science (ARS)	9758	3.62	0.95	1.00	5.00
SES	9758	0.04	0.67	-0.99	2.67
Afrc-Ame	9758	0.15	0.36	0.00	1.00
Hispanic	9758	0.14	0.35	0.00	1.00
Asian	9758	0.05	0.22	0.00	1.00
Others	9758	0.06	0.24	0.00	1.00
Male	9758	0.51	0.50	0.00	1.00
		Level – 2			
CHCLDS	687	2.65	0.59	1.00	5.00
OFTSCI	687	3.51	0.68	2.00	5.00
TXSCI	687	1.32	0.39	1.00	3.00
EQUIPM	687	3.66	1.20	0.00	6.00

Note. N=Sample size; SD= Standard deviation.

Table 4.7

Science IRT & ARS Scores by Gender in Kindergarten Level

	IRT		ARS	
	M	SD	M	SD
Male	27.28	7.75	3.56	0.96
Female	26.91	7.39	3.68	0.93
Total	27.10	7.58	3.62	0.95

Note. M=Mean; SD= Standard deviation.

The average science IRT score was 27.10 (SD=7.58) and the average science ARS score was 3.62 (SD=0.95). The IRT and ARS science scores by gender are presented in Table 4.7. The results indicated that male students' consistently outperformed their female classmates on IRT scales (Cohen's Effect Size, d=0.05). In contrast, according to the ARS scores female students performed better than male students (Cohen's Effect Size, d=0.13).

It is noteworthy that here that the ARS scores are teachers' ratings of their students based on their past and current observations of the students' performance in their classroom.

Table 4.8

Correlations among Outcome Measures and Level – 2 Variables (Kindergarten)

	IRT	ARS	SES	CHCLDS	OFTSCI	TXSCI	EQUIPM
IRT	1.00						
ARS	.428**	1.00					
SES	.433**	.251**	1.00				
CHCLDS	-008**	.032**	-003**	1.00			
OFTSCI	.013**	.083**	-.001	.190**	1.00		
TXSCI	-018**	.037**	.026**	.128**	.245**	1.00	
EQUIPM	.055**	.068**	.080	.209**	.294**	.118**	1.00

Note 1. ** Correlation is significant at the 0.01 level (2-tailed).

Note 2. Correlations were computed using weighting variable C2CW0

Pearson Product correlations were calculated for the science measures, SES, and categories of classroom practices. The findings are reported in Table 4.8. There were significant correlations between the IRT and ARS scores and between IRT and SES (*r*=.428 and *r*=.433). There were other weak, yet significant, correlations as noted in Table 4.8.

Kindergarten Results

Kindergarten – IRT Results

Unconditional model.

$$Science(IRT)_{jk} = \beta_{0k} + r_{jk}$$

Where we assume r_{jk} ~ independently N (0, σ^2) for j=1,…, n_j students in school k, and k= 1,…, 687 schools. We refer to σ^2 as the student-level variance.

$$\beta_{0k} = \gamma_{00} + u_{0k}$$

Where we assume u_{0k} ~ independently N (0, τ_{00}). We refer to τ_{00} as the school level variance.

Table 4.9

Fully Unconditional Model of Science IRT Scores (Kindergarten)

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Average school mean, γ_{00}	26.70**	0.17	152.80	
Random Effect	*Variance*	*df*	χ^2	*p-value*
School mean status, u_{0k}	15.19	686	4105.67	0.001
Level-1 Effect, r_{jk}	42.29			

Deviance = 65438.21 with 2 *df*

**p<0.001

Table 4.9 presents the fully unconditional model of science IRT scores in kindergarten. The weighted least square estimate for the grand mean science (IRT) scores in spring semester at the Kindergarten level was 26.70 (γ_{00}) with a standard error of 0.17 (t=152.80, p=<.001) yielding 95% confidence interval of 26.36-27.03. The second part of Table 4.9 lists the restricted maximum likelihood estimates of the variance components. The expected student level variance was r_{jk}=42.29. There was significant variation among the schools (χ^2 = 4105.67, p=<.001). The estimated variability in the school means was 15.19 (u_{0k}) and the *plausible values range* for these means were; 26.70±1.96 $(15.19)^{1/2}$ = (19.08, 34.32).

The findings suggest that there was a substantial range in average achievement levels among schools in this sample of kindergarten science (IRT) data. The proportion of variance between schools (*intraclass correlation*) was also estimated by substituting the estimated variance components for their respective parameters in the following equation: $\tau_{00}/(\tau_{00}+\sigma^2)=0.26$. This suggests that about 26% of the variance in science (IRT) achievement was between schools. Deviance for the unconditional model was 65438.49 with 2 estimated parameters (see Table 4.9).

Student model.

<u>Level – 1 Model:</u>

$$Science(IRT)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Male) + \beta_{3k}(Afrc - Ame) + \beta_{4k}(Hispanic) + \beta_{5k}(Asian) + \beta_{6k}(Others) + r_{jk}$$

Where;

β_{0k} : Predicted Science (IRT) achievement for a student who is female, Caucasians and average on SES in school *k*th.

β_{1k} : The differentiating effect of social class (SES) in the *k*th school, after controlling the effects of individual student's gender and race/ethnicity.

β_{2k} : The adjusted mean difference between science achievement of female students versus male students in the *k*th school after controlling the effects of individual student's SES and race/ethnicity.

β_{3k} : The adjusted mean difference between science achievements of African American students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{4k} : The adjusted mean difference between science achievements of Hispanic students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{5k} : The adjusted mean difference between science achievements of Asian students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{6k} : The adjusted mean difference between science achievement of others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and race/ethnicity groups.

r_{jk} : Unexplained residual variance at Level -1 after taking account into students' social status (SES), gender, and race/ethnicity.

Level – 2 Model:

$$\beta_{0k} = \gamma_{00} + u_{0k}$$
$$\beta_{1k} = \gamma_{10}$$
$$\beta_{2k} = \gamma_{20}$$
$$\beta_{3k} = \gamma_{30}$$
$$\beta_{4k} = \gamma_{40}$$
$$\beta_{5k} = \gamma_{50}$$
$$\beta_{6k} = \gamma_{60}$$

Table 4.10 reports the effects of student level variables on children's science (IRT) scores. The student level model results indicated that the average school (IRT) score mean was 28.47, γ_{00}, (*se*= 0.13, *t*=214.40, *p*=<.001) for the reference student. The reference student for the student model was Caucasian, female student who had an average socioeconomic status (SES). The average SES-achievement slope was 3.72, γ_{10}, and the effect of SES on the estimated science (IRT) achievement was found to be statistically significant (*se*= 0.12, *t*=30.62, *p*=<.001). This indicates that a student with one standard deviation higher SES level scored 3.72 points higher than others. Male students' science achievement on the IRT scale was 0.31, γ_{20}, points higher than female students (*se*= 0.13, *t*=2.24, *p*=<.05). On the other hand, when African – American, Hispanic, Asian, and Other students compared with their Caucasian counterparts, the results indicated that they had 4.92, γ_{30}, (*se*= 0.24, *t*=-19.71, *p*=<.001) ; 3.37 , γ_{40}, (*se*= 0.24, *t*=-13.81, *p*=<.001); 5.02, γ_{50}, (*se*= 0.38, *t*=-13.18, *p*=<.001); and 2.63, γ_{60}, (*se*= 0.35, *t*=-7.35, *p*=<.001) points lower than his/her their Caucasian classmates in school *k*, respectively.

Table 4.10

Effects of Student – Level (K) Characteristics on Children's Science (IRT) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Intercept, β_{0k}				
Overall mean achievement, γ_{00}	28.47**	0.13	214.40	
Mean **SES**-achievement slope, β_{1k}				
Intercept, γ_{10}	3.72**	0.12	30.62	
Mean Male-achievement slope, β_{2k}				
Intercept, γ_{20}	0.31*	0.13	2.24	
Mean Afrc-Ame- achievement slope, β_{3k}				
Intercept, γ_{30}	-4.92**	0.24	-19.71	
Mean Hispanic- achievement slope, β_{4k}				
Intercept, γ_{40}	-3.37**	0.24	-13.81	
Mean Asian achievement slope, β_{5k}				
Intercept, γ_{50}	-5.02**	0.38	-13.18	
Mean Others- achievement slope, β_{6k}				
Intercept, γ_{60}	-2.63**	0.35	-7.35	
Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	3.61	686	1652.71	0.001
Student level error, r_{jk}	37.64			

Deviance = 63677.87 with 2 *df*

**p*<0.05, ***p*<0.001

The estimated variance among the means was 3.61 (u_{0k}) with related chi-statistics of 1652.71 (*p*=<.001). The *plausible values range* for these means was;

$$28.47 \pm 1.96\ (3.61)^{1/2} = (24.74,\ 32.19)$$

The results for the school means were similar to those previously reported for the unconditional model. The range, however, was narrower [(19.08, 34.32) vs. (24.74, 32.19)]. Additionally, adding SES, gender and race/ethnicity variables as predictors of science (IRT) achievement reduced the within-school variance by 10.9%. The deviance for the student model was 63677.87, and the number of estimated parameters was 2.

School model.

Level – 1 Model:

$$Science(IRT)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Male) + \beta_{3k}(Afrc - Ame) + \beta_{4k}(Hispanic) + \beta_{5k}(Asian) + \beta_{6k}(Others) + r_{jk}$$

Level – 2 Model:

$$\beta_{0k} = \gamma_{00} + u_{0k}$$
$$\beta_{1k} = \gamma_{10}$$
$$\beta_{2k} = \gamma_{20}$$
$$\beta_{3k} = \gamma_{30}$$
$$\beta_{4k} = \gamma_{40}$$
$$\beta_{5k} = \gamma_{50}$$
$$\beta_{6k} = \gamma_{60} + \gamma_{61}(CHCLDS) + \gamma_{62}(OFTSCI)$$

Where;

γ_{00} : The average of the school means on science (IRT) achievement for Caucasian, females of average SES across the population of schools.

γ_{10} : The average SES-science (IRT) slope across schools that represents the predicted change in science (IRT) score for one unit change in SES, controlling for gender and race/ethnicity.

γ_{20} : The average male –science (IRT) regression slope across schools that represents the gap between female and male students, controlling for SES and race/ethnicity.

γ_{30} : The average African-American –science (IRT) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES and gender.

γ_{40} : The average Hispanic –science (IRT) regression slope across schools that represents the gap between Hispanic and Caucasian students, controlling for SES and gender.

γ_{50} : The average Asian –science (IRT) regression slope across schools that represents the gap between Asian and Caucasian students, controlling for SES and gender.

γ_{60} : The average Others –science (IRT) regression slope across schools that represents the gap between Others and Caucasian students, controlling for SES and gender.

γ_{61} : The effect of CHCLDS (child selected activities) on the adjusted mean difference between science achievements of Others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) students versus Caucasian students in the *k*th school.

γ_{62} : The effect of OFTSCI (frequency of science instructions) on the adjusted mean difference between science achievements of Others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) students versus Caucasian students in the *k*th school.

u_{0k} : The unique increment to the intercept associated with school *k*.

The school model results were similar to the student model. The average school science (IRT) mean was 28.48, γ_{00} , (*se*= 0.13, *t*=214.71, *p*=<.001) for the reference student (Female=0, Caucasian=0, and with average SES status) (Table 4.11). While children's SES level and gender were positively associated with the average school science (IRT) achievement significantly, their race/ethnicity was negatively associated. On average as the students' SES level increased one unit, the science (IRT) achievement of children increased about γ_{10} =3.71 points (*se*= 0.12, *t*=30.47, *p*=<.001). Students' gender was also significantly related γ_{20} =0.32 (*se*= 0.13, *t*=2.35, *p*=<.05) with male students' scores .32 points higher than their female classmates.

The effect of children's race/ethnicity revealed that on average science achievement scores obtained by African-American students 4.94 (*p*=<.001), Hispanic students 3.39 (*p*=<.001), Asian students 5.04 (*p*=<.001), and children from 'others' group 2.63 (*p*=<.001) were lower than the scores obtained by Caucasian children. It was also found that children's scores from the 'others' group (Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) were negatively associated with 'child-selected activities' (γ_{61} =-2.59, *se*= 0.55, *t*=-4.70, *p*=<.001), after controlling for the frequency of science instruction. The data suggest that children from this group did not benefit from activities that were organized in a manner that gave children opportunities to select their own activities. The student from the same group positively benefited from more having frequent science activities (γ_{62} =1.23, *se*= 0.46, *t*=2.67, *p*=<.05), after controlling for child-selected activities.

Table 4.11
Effects of School – Level (K) Characteristics on Children's Science (IRT) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Intercept, β_{0k}				
Overall mean achievement, γ_{00}	28.48^{**}	0.13	214.71	
Mean SES-achievement slope, β_{1k}				
Intercept, γ_{10}	3.71^{**}	0.12	30.47	
Mean Male-achievement slope, β_{2k}				
Intercept, γ_{20}	0.32^{*}	0.13	2.35	
Mean Afrc-Ame- achievement slope, β_{3k}				
Intercept, γ_{30}	-4.94^{**}	0.25	-19.73	
Mean Hispanic- achievement slope, β_{4k}				
Intercept, γ_{40}	-3.39^{**}	0.24	-13.88	
Mean Asian achievement slope, β_{5k}				
Intercept, γ_{50}	-5.04^{**}	0.38	-13.25	
Mean Others- achievement slope, β_{6k}				
Intercept, γ_{60}	-2.63^{**}	0.33	-7.93	
CHCLDS, γ_{61}	-2.59^{**}	0.55	-4.70	
OFTSCI, γ_{62}	1.23^{*}	0.46	2.67	
Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	3.50	686	1624.14	0.001
Student level error, r_{jk}	37.61			

Deviance = 63655.71 with 2 *df*
$^{*}p<0.05$, $^{**}p<0.001$

Table 4.11 also provides the test statistics of the each variance components. The estimated variance among the means was 3.50 (χ^2 =1624.14, *df*=686, *p*=<.001) and the range of plausible values for the school mean was 28.48±1.96 $(3.50)^{1/2}$ = (24.82, 32.14). Variance-explained statistics were calculated as 3%. This means that only 3% of the parameter variation in school achievement means has been explained by school-level variables (CHCLDS and OFTSCI). Deviance statistics for the current covariance components model was 63655.71 and the number of estimated parameters was 2.

Kindergarten – ARS Results

Unconditional model.

$$Science(ARS)_{jk} = \beta_{0k} + r_{jk}$$

Where we assume r_{jk} ~ independently N (0, σ^2) for *j*=1,…, n_j students in school *k*, and k= 1,…, 687 schools. We refer to σ^2 as the student-level variance.

$$\beta_{0k} = \gamma_{00} + u_{0k}$$

Where we assume u_{0k} ~ independently N (0, τ_{00}). We refer to τ_{00} as the school level variance.

Table 4.12

Fully Unconditional Model of ARS Science (Kindergarten)

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Average school mean, γ_{00}	3.58**	0.02	170.84	
Random Effect	*Variance*	*df*	χ^2	*p-value*
School-mean status, u_{0k}	0.19	686	3378.01	0.001
Level-1 Effect, r_{jk}	0.71			

Deviance = 25473.35 with 2 *df*

***p*<0.001

The weighted least square estimate for the grand mean science (ARS) scores at the Kindergarten level was 3.58 (γ_{00}) with a standard error of 0.02 (*t*=170.84, *p*=<.001) yielding a 95% confidence interval of 3.54-3.62. The second part of Table 4.12 lists restricted maximum likelihood estimates of the variance components. The expected student level variance was r_{jk}=0.71. There was significant variation among the schools (χ^2 = 3378.01, *p*=<.001). The estimated variability in these school means was 0.19 (u_{0k}) and the *plausible values range* for these means were;

$$3.58 \pm 1.96\ (0.19)^{1/2} = (2.73,\ 4.43)$$

This suggests a substantial range in average achievement levels among schools in this sample of kindergarten science achievement (ARS) data. The proportion of variance between schools (*intraclass correlation*) was also estimated by substituting the estimated variance components for their respective parameters in the following equation:

$$\tau_{00} / (\tau_{00} + \sigma^2) = 0.21$$

This indicted that about 21% of the variance in science (ARS) achievement was between schools. Deviance for the unconditional model was 25473.35 with 2 estimated parameters (Table 4.12).

Student model.

Level – 1 Model:

$$Science(ARS)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Male) + \beta_{3k}(Afrc - Ame) + \beta_{4k}(Hispanic) + \beta_{5k}(Asian) + \beta_{6k}(Others) + r_{jk}$$

Where;

β_{0k} : Predicted Science (ARS) achievement for a student who is female, Caucasians and average on SES in school *k*th.

β_{1k} : The differentiating effect of social class (SES) in the *k*th school, after controlling the effects of individual student's gender and race/ethnicity.

β_{2k} : The adjusted mean difference between science achievement of female students versus male students in the *k*th school after controlling the effects of individual student's SES and race/ethnicity.

β_{3k} : The adjusted mean difference between science achievements of African American students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{4k} : The adjusted mean difference between science achievements of Hispanic students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{5k} : The adjusted mean difference between science achievements of Asian students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{6k} : The adjusted mean difference between science achievements of Others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and race/ethnicity groups.

r_{jk} : Unexplained residual variance at Level -1 after taking account into students' social status (SES), gender, and race/ethnicity.

Level – 2 Model:

$$\beta_{0k} = \gamma_{00} + u_{0k}$$
$$\beta_{1k} = \gamma_{10} + u_{1k}$$
$$\beta_{2k} = \gamma_{20}$$
$$\beta_{3k} = \gamma_{30} + u_{3k}$$
$$\beta_{4k} = \gamma_{40}$$
$$\beta_{5k} = \gamma_{50}$$
$$\beta_{6k} = \gamma_{60}$$

Table 4.13 lists the effects of student level variables on children's science (ARS) scores. The student level model results indicated that the average school (ARS) score mean was 3.74, γ_{00}, (*se*= 0.02, *t*=154.38, *p*=<.001) for the reference student. The reference student for the student model was a female Caucasian student who had an average socioeconomic status (SES). The average SES-achievement slope was 0.34, γ_{10}, and the effect of SES on the estimated science (ARS) achievement was found to be statistically significant (*se*= 0.02, *t*=19.03, *p*=<.001). This indicates that a student with one standard deviation higher SES level scored 0.34 points higher than others. Male students' science achievement on the ARS scale was 0.13, γ_{20}, points lower than female students (*se*= 0.01, *t*=-7.49, *p*=<.001). When African – American, Hispanic, Asian, and Other students were compared with their Caucasian counterparts, the results indicated that their scores were 0.19, γ_{30}, (*se*= 0.03, *t*=-5.59, *p*=<.001) ; 0.16 , γ_{40}, (*se*= 0.03, *t*=-4.46, *p*=<.001); 0.09, γ_{50}, (*se*= 0.04, *t*=-2.36, *p*=<.05); and 0.15, γ_{60}, (*se*= 0.04, *t*=-3.28, *p*=<.001) lower than their Caucasian classmates in school *k*, respectively.

Table 4.13

Effects of Student – Level (K) Characteristics on Children's Science (ARS) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Intercept, β_{0k}				
Overall mean achievement, γ_{00}	3.74^{**}	0.02	154.38	
Mean SES-achievement slope, β_{1k}				
Intercept, γ_{10}	0.34^{**}	0.01	19.03	
Mean Male-achievement slope, β_{2k}				
Intercept, γ_{20}	-0.13^{**}	0.01	-7.49	
Mean Afrc-Ame- achievement slope, β_{3k}				
Intercept, γ_{30}	-0.19^{**}	0.03	-5.59	
Mean Hispanic- achievement slope, β_{4k}				
Intercept, γ_{40}	-0.16^{**}	0.03	-4.46	
Mean Asian achievement slope, β_{5k}				
Intercept, γ_{50}	-0.09^{*}	0.04	-2.36	
Mean Others- achievement slope, β_{6k}				
Intercept, γ_{60}	-0.15^{**}	0.04	-3.28	
Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	0.16	291	983.34	0.001
SES slope, u_{1k}	0.02	291	369.18	0.002
Afrc-Ame slope, u_{3k}	0.04	291	337.93	0.030
Student level error, r_{jk}	0.65			

Deviance = 24798.49 with 7 *df*

**p*<0.05, ***p*<0.001

The estimated variance among school means was 0.16 (u_{0k}) with related chi-statistics of 983.34 (p=<.001). The average SES-achievement slope was u_{1k}=0.02 (χ^2=369.18, p=.002) and African-American-achievement slope was u_{3k}=0.04 (χ^2=337.93, p=.030). The *plausible values range* for school means was (2.96, 4.52), for SES-achievement slope was (0.07, 0.61), and for African-American-achievement slope was (-0.58, 0.2).

Additionally, adding SES, gender and race/ethnicity variables as predictors of science (ARS) achievement reduced the within-school variance by 8.4%. Deviance for the student model was 24798.49 and the number of estimated parameters was 7.

School model.

<u>*Level – 1 Model:*</u>

$$Science(ARS)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Male) + \beta_{3k}(Afrc - Ame) + \beta_{4k}(Hispanic) + \beta_{5k}(Asian) + \beta_{6k}(Others) + r_{jk}$$

<u>*Level – 2 Model:*</u>

$$\beta_{0k} = \gamma_{00} + \gamma_{01}(OFTSCI) + u_{0k}$$
$$\beta_{1k} = \gamma_{10} + \gamma_{11}(CHCLDS) + u_{1k}$$
$$\beta_{2k} = \gamma_{20}$$
$$\beta_{3k} = \gamma_{30} + \gamma_{31}(EQUIPM) + u_{3k}$$
$$\beta_{4k} = \gamma_{40} + \gamma_{41}(OFTSCI) + \gamma_{42}(TXSCI)$$
$$\beta_{5k} = \gamma_{50}$$
$$\beta_{6k} = \gamma_{60}$$

Where;

γ_{00}: The average of the school means on science (ARS) achievement for Caucasian, females of average SES across the population of schools.

γ_{01}: The effect of OFTSCI (frequency of science instructions) on the average of the school means on science (ARS) achievement for Caucasian, females of average SES across the population of schools.

γ_{10}: The average SES-science (ARS) slope across schools that represents the predicted change in science (ARS) score for one unit change in SES, controlling for gender and race/ethnicity.

γ_{11}: The effect of CHCLDS (child-selected activities) on the average SES-science (ARS) slope across schools that represents the predicted change in science (ARS) score for one unit change in SES, controlling for gender and race/ethnicity.

γ_{20}: The average male –science (ARS) regression slope across schools that represents the gap between female and male students, controlling for SES and race/ethnicity.

γ_{30}: The average African-American –science (ARS) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES and gender.

γ_{31}: The effect of EQUIPM (Frequency of science equipment use) on the average African-American –science (ARS) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES and gender.

γ_{40}: The average Hispanic –science (ARS) regression slope across schools that represents the gap between Hispanic and Caucasian students, controlling for SES and gender.

γ_{41}: The effect of OFTSCI (frequency of science instructions) on the average Hispanic –science (ARS) regression slope across schools that represents the gap between Hispanic and Caucasian students, controlling for SES, gender and TXSCI.

γ_{42}: The effect of TXSCI (time for science) on the average Hispanic –science (ARS) regression slope across schools that represents the gap between Hispanic and Caucasian students, controlling for SES, gender and OFTSCI.

γ_{50}: The average Asian –science (ARS) regression slope across schools that represents the gap between Asian and Caucasian students, controlling for SES and gender.

γ_{60}: The average Others –science (ARS) regression slope across schools that represents the gap between Others and Caucasian students, controlling for SES and gender.

u_{0k}, u_{1k}, &, u_{3k} : The unique increment to the intercept associated with school *k*.

The average school science (ARS) mean was 3.74, γ_{00}, (*se*= 0.02, *t*=155.24, *p*=<.001) for the reference student (Female=0, Caucasian=0, and with average SES status) (Table 4.14). In these schools students' science (ARS) mean achievement scores seemed to increase as a function of frequency of science instruction (OFTSCI) by about .08 points (γ_{01}=0.08, *se*= 0.03, *p*=<.05). Additionally, children with average SES level benefited more from child-selected activities (CHCLDS), and their scores were 0.07 points higher than the reference students (γ_{11}=0.07, *se*= 0.03, *p*=<.05) as shown in Table 4.14.

There was a significant but negative effects of gender on students' science (ARS) scores γ_{20}=-0.13 (*se*= 0.01, *t*=-7.54, *p*=<.001) with female students' scores .13 points higher than their male classmates within schools. The effects of children's race/ethnicity revealed that the science achievement scores of African-American students 0.20 (*p*=<.001), Hispanic students 0.16 (*p*=<.001), Asian students 0.09 (*p*=<.05), and children from the 'others' group 0.15 (*p*=<.05) were lower than Caucasian children's scores. It was also found that African-American children's science (ARS) scores increased when they had more opportunities to use science equipment (EQUIPM) (γ_{31}=0.05, *se*= 0.02, *t*=1.96, *p*=<.05).

Hispanic children, however, did not benefit from frequency of science activities (γ_{41}=-0.10, *se*= 0.05, *t*=-2.01, *p*=<.05), after controlling for time for science (TXSCI). On the other hand, when the same group of children more time for science activities (TXSCI) their science (ART) scores seemed to increase by about .24 points (γ_{42}=0.24, *se*= 0.08, *t*=2.75, *p*=<.05), after controlling for frequency of science instructions (OFTSCI).

Table 4.14 also reports the test statistics for each of the variance components. The estimated variance among school means was 0.16, u_{0k}, (χ^2=962.55, *df*=290, *p*=<.001) and the range of plausible values for the school means was; $3.74 \pm 1.96\,(0.16)^{1/2} = (2.96, 4.52)$. Adding level-3 variables as predictors of science (ARS) achievement did not have an effect on within-school variance. School level variance, u_{0k}, remained to be same (0.16).

Deviance for the student model was 24790.59 and the number of estimated parameters was 7.

Table 4.14

Effects of School – Level (K) Characteristics on Children's Science (ARS) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*
Intercept, β_{0k}			
Overall mean achievement, γ_{00}	3.74^{**}	0.02	155.24
OFTSCI, γ_{01}	0.08^{*}	0.03	2.74
Mean SES-achievement slope, β_{1k}			
Intercept, γ_{10}	0.34^{**}	0.01	19.24
CHCLDS, γ_{11}	0.07^{*}	0.03	2.42
Mean Male-achievement slope, β_{2k}			
Intercept, γ_{20}	-0.13^{**}	0.01	-7.54
Mean Afrc-Ame- achievement slope, β_{3k}			
Intercept, γ_{30}	-0.20^{**}	0.03	-6.05
EQUIPM, γ_{31}	0.05^{*}	0.02	1.96
Mean Hispanic- achievement slope, β_{4k}			
Intercept, γ_{40}	-0.16^{**}	0.03	-4.31
OFTSCI, γ_{41}	-0.10^{*}	0.05	-2.01
TXSCI, γ_{42}	0.24^{*}	0.08	2.75
Mean Asian achievement slope, β_{5k}			
Intercept, γ_{50}	-0.09^{*}	0.04	-2.30
Mean Others- achievement slope, β_{6k}			
Intercept, γ_{60}	-0.15^{*}	0.04	-3.15

Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	0.16	290	962.55	0.001
SES slope, u_{1k}	0.02	290	369.45	0.001
Afrc-Ame slope, u_{3k}	0.04	290	339.32	0.024
Student level error, r_{jk}	0.65			

Deviance = 24790.59 with 7 *df*

$^{*}p<0.05$, $^{**}p<0.001$

First-Grade Results

The first-grade data consisted of 5577 students nested within 570 schools. The mean science score (IRT) was 35.70, SD =6.85 with a minimum score of 10.50 and maximum of 48.91. This means that the students' IRT scores cover the entire range of possible scores. The mean ARS science score was 3.39, SD =0.94 with a minimum score of 1.00 and a maximum of 5.00. The SES distribution of children in kindergarten ranged between -0.99 and 2.88 (Mean: 0.16, SD =0.72). There was close to an equal number of male and female students in the sample (N_{male}=2781 vs. N_{female}=2796).

Table 4.15

Descriptive Statistics for First-grade Level Science IRT & ARS Score Analysis

Variables	N	Mean	SD	Minimum	Maximum
		Level – 1			
Science (IRT)	5577	35.70	6.85	10.50	48.91
Science (ARS)	5577	3.39	0.94	1.00	5.00
SES	5577	0.16	0.72	-0.99	2.88
Afrc-Ame	5577	0.10	0.30	0.00	1.00
Hispanic	5577	0.13	0.34	0.00	1.00
Asian	5577	0.05	0.23	0.00	1.00
Others	5577	0.04	0.21	0.00	1.00
Male	5577	0.50	0.50	0.00	1.00
		Level – 2			
CHCLDS	570	2.40	0.58	1.00	5.00
OFTSCI	570	3.52	0.63	2.00	5.00
TXSCI	570	1.52	0.44	1.00	3.00
EQUIPM	570	3.16	1.16	0.00	6.00

Note. N=Sample size; SD= Standard deviation.

The majority of the participants were Caucasian (67%) followed by African-American (10.1%), Hispanic (13.1%), Others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) (4.5%), and Asian (5.4%). Table 4.15 presents the sample size (*n*), means, and standard deviations for values for both student- and school-level variables.

Table 4.16

Science IRT and ARS Scores by Gender in First-grade Level

	IRT		ARS	
	M	SD	M	SD
Male	36.12	6.85	3.35	0.95
Female	35.26	6.81	3.42	0.92
Total	35.69	6.85	3.38	0.93

Note. M=Mean; SD= Standard deviation.

The average science IRT score was 35.69 (SD=6.85) and the average science ARS score was 3.38 (SD=0.93). Both IRT and ARS science scores on science achievement by gender are presented in Table 4.16. The results indicated that male students' consistently outperformed their female classmates based on the IRT scales (Cohen's Effect Size, d=0.13). The ARS scales are based on teachers' ratings of their students based on past and current classroom performance. The data indicated that female students out performed male students (Cohen's Effect Size, d=0.07).

Table 4.17

Correlations among Outcome Measures and Level – 2 Variables (First-grade)

	IRT	ARS	SES	CHCLDS	OFTSCI	TXSCI	EQUIPM
IRT	1.00						
ARS	.381**	1.00					
SES	.379**	.218**	1.00				
CHCLDS	.021**	.036**	.048**	1.00			
OFTSCI	-004**	.008**	-025**	.115**	1.00		
TXSCI	.023**	.062**	.024**	.081**	.122**	1.00	
EQUIPM	.081**	.062**	.137**	.142**	.209**	.111**	1.00

Note 1. ** Correlation is significant at the 0.01 level (2-tailed).

Note 2. Correlations were computed using weighting variable C4CW0.

Pearson Product correlations between science measures, SES, and Level – 2 variables in first-grade level are reported in Table 4.17. The IRT - ARS and the IRT - SES scores were moderately correlated, *r*= .381 and *r* =.379, respectively. Science scores based on the IRT scale scores were positively, yet weakly, correlated with Level-2 variables except for the OFTSCI variable (r=-.004). The ARS scale score was also positively correlated with all Level-2 variables and with the SES variable.

First-grade – IRT Results

Unconditional model.

$$Science(IRT)_{jk} = \beta_{0k} + r_{jk}$$

Where we assume r_{jk} ~ independently N (0, σ^2) for *j*=1,…, n_j students in school *k*, and k= 1,…, 570 schools. We refer to σ^2 as the student-level variance.

$$\beta_{0k} = \gamma_{00} + u_{0k}$$

Where we assume u_{0k} ~ independently N (0, τ_{00}). We refer to τ_{00} as the school level variance.

Table 4.18

Fully Unconditional Model of IRT Science Scores (First-grade)

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Average school mean, γ_{00}	35.05**	0.19	181.05	
Random Effect	*Variance*	*df*	χ^2	*p-value*
School mean status, u_{0k}	13.13	569	2570.53	0.001
Level-1 Effect, r_{jk}	34.08			

Deviance = 36360.39 with 2 *df*

$^{**}p<0.001$

The weighted least square estimate for the grand mean science (IRT) scores in first-grade was 35.05 (γ_{00}) with the standard error of 0.19 (*t*=181.05, *p*=<.001) yielding a 95% confidence interval of 34.68-35.42. The second part of Table 4.18 lists restricted maximum likelihood estimates of the variance components. The expected student level variance was r_{jk}=34.08. There was significant variation among the schools (χ^2 = 2570.53, *p*=<.001). The estimated variability in these school means was 13.13 (u_{0k}) and the *plausible values range* for these means were;

$$35.05 \pm 1.96\ (13.13)^{1/2} = (27.96,\ 42.14)$$

This indicates a substantial range in average achievement levels among schools in this sample of science (IRT) data in the first-grade level. The proportion of variance between schools (*intraclass correlation*) was also estimated by substituting the estimated variance components for their respective parameters in following equation:

$$\tau_{00} / (\tau_{00} + \sigma^2) = 0.28$$

This indicted that about 28% of the variance in science (IRT) achievement was between schools. Deviance for the unconditional model was 36360.39 with 2 estimated parameters (Table 4.18).

Student model.

<u>Level – 1 Model:</u>

$$Science(IRT)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Male) + \beta_{3k}(Afrc - Ame) + \beta_{4k}(Hispanic) + \beta_{5k}(Asian) + \beta_{6k}(Others) + r_{jk}$$

Where;

β_{0k} : Predicted Science (IRT) achievement for a student who is female, Caucasians and average on SES in school *k*th.

β_{1k} : The differentiating effect of social class (SES) in the *k*th school, after controlling the effects of individual student's gender and race/ethnicity.

β_{2k} : The adjusted mean difference between science achievement of female students versus male students in the *k*th school after controlling the effects of individual student's SES and race/ethnicity.

β_{3k} : The adjusted mean difference between science achievements of African American students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{4k} : The adjusted mean difference between science achievements of Hispanic students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{5k} : The adjusted mean difference between science achievements of Asian students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

β_{6k} : The adjusted mean difference between science achievements of Others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and race/ethnicity groups.

r_{jk} : Unexplained residual variance at Level -1 after taking account into students' social status (SES), gender, and race/ethnicity.

Level – 2 Model:

$$\beta_{0k} = \gamma_{00} + u_{0k}$$
$$\beta_{1k} = \gamma_{10} + u_{1k}$$
$$\beta_{2k} = \gamma_{20} + u_{2k}$$
$$\beta_{3k} = \gamma_{30} + u_{3k}$$
$$\beta_{4k} = \gamma_{40} + u_{4k}$$
$$\beta_{5k} = \gamma_{50}$$
$$\beta_{6k} = \gamma_{60}$$

Table 4.19 lists the effects of student level variables on children's science (IRT) scores in 1st grade. The student level model indicated that the average school (IRT) score mean was 36.46, γ_{00} , (*se*= 0.16, *t*=220.57, *p*=<.001) for the reference student. The reference student for the student model was Caucasian, female student who had an average socioeconomic status (SES). The average SES-achievement slope was 2.69, γ_{10} , and the effect of SES on the estimated science (IRT) achievement was found to be statistically significant (*se*= 0.14, *t*=18.52, *p*=<.001). This indicates that a student with one standard deviation higher SES level scored 2.69 points higher than others. Male students' science achievement on the IRT scale was 1.00, γ_{20} , points higher than female students (*se*= 0.18, *t*=5.36, *p*=<.001). On the other hand, when African – American, Hispanic, Asian, and Others students are compared to their Caucasian counterparts, the results indicated that their scores were 4.88, γ_{30}, (*se*= 0.46, *t*=-10.44, *p*=<.001) ; 3.79 , γ_{40}, (*se*= 0.35, *t*=-10.64, *p*=<.001); 3.99, γ_{50}, (*se*= 0.47, *t*=-8.47, *p*=<.001); and 2.32, γ_{60}, (*se*= 0.61, *t*=-3.77, *p*=<.001) points lower than their Caucasian classmates in school *k*, respectively.

Table 4.19

Effects of Student – Level (First-grade) Characteristics on Children's Science (IRT) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*
Intercept, β_{0k}			
Overall mean achievement, γ_{00}	36.46^{**}	0.16	220.57
Mean SES-achievement slope, β_{1k}			
Intercept, γ_{10}	2.69^{**}	0.14	18.52
Mean Male-achievement slope, β_{2k}			
Intercept, γ_{20}	1.00^{**}	0.18	5.36
Mean Afrc-Ame- achievement slope, β_{3k}			
Intercept, γ_{30}	-4.88^{**}	0.46	-10.44
Mean Hispanic- achievement slope, β_{4k}			
Intercept, γ_{40}	-3.79^{**}	0.35	-10.64
Mean Asian achievement slope, β_{5k}			
Intercept, γ_{50}	-3.99^{**}	0.47	-8.47
Mean Others- achievement slope, β_{6k}			
Intercept, γ_{60}	-2.32^{**}	0.61	-3.77

Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	3.01	72	146.77	0.001
SES slope, u_{1k}	0.92	72	105.32	0.007
Male slope, u_{2k}	1.40	72	116.67	0.001
Afrc-Ame slope, u_{3k}	13.68	72	91.52	0.050
Hispanic slope, u_{4k}	7.36	72	142.48	0.001
Student-level error, r_{jk}	29.28			

Deviance = 35337.39 with 16 *df*

$^{**}p<0.001$

The estimated variance among means was 3.01 (u_{0k}) with related chi-statistics of 146.77 (*p*=<.001). The average SES-achievement slope was u_{1k}=0.92 (χ^2=105.32, *p*=.007), the Male-achievement slope was u_{2k}=1.40 (χ^2=116.67, *p*=.001), the African-American-achievement slope was u_{3k}=13.68 (χ^2=91.52, *p*=.05), and the Hispanic-achievement slope was u_{4k}=7.36 (χ^2=142.48, *p*=.001). These results indicated that the relationships between SES, gender, African-American, and Hispanic and Science (IRT) achievement within schools varied significantly across the population of schools. Additionally, the student-level error was, r_{jk}, 29.28.

The *plausible values range* for school means was (33.07, 39.85), for the SES-achievement slope was (0.83, 4.55), for the Male-achievement slope was (1.31, 3.31), for the African-American-achievement slope was (-12.11, 2.35), and for the Hispanic-achievement slope was (-9.1, 1.52). Additionally, adding SES, gender and race/ethnicity variables as predictors of science (IRT) achievement reduced within-school variance by 14%. Deviance for the student model was 35337.39 and the number of estimated parameters was 16.

School model.

<u>Level – 1 Model:</u>

$$Science(IRT)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Male) + \beta_{3k}(Afrc - Ame) + \beta_{4k}(Hispanic) + \beta_{5k}(Asian) + \beta_{6k}(Others) + r_{jk}$$

<u>Level – 2 Model:</u>

$$\beta_{0k} = \gamma_{00} + u_{0k}$$
$$\beta_{1k} = \gamma_{10} + u_{1k}$$
$$\beta_{2k} = \gamma_{20} + u_{2k}$$
$$\beta_{3k} = \gamma_{30} + \gamma_{31}(TXSCI) + u_{3k}$$
$$\beta_{4k} = \gamma_{40} + \gamma_{41}(EQUIPM) + u_{4k}$$
$$\beta_{5k} = \gamma_{50} + \gamma_{51}(OFTSCI)$$
$$\beta_{6k} = \gamma_{60}$$

Where;

γ_{00} : The average of the school means on science (IRT) achievement for Caucasian, females of average SES across the population of schools.

γ_{10} : The average SES-science (IRT) slope across schools that represents the predicted change in science (IRT) score for one unit change in SES, controlling for gender and race/ethnicity.

γ_{20} : The average male –science (IRT) regression slope across schools that represents the gap between female and male students, controlling for SES and race/ethnicity.

γ_{30} : The average African-American –science (IRT) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES and gender.

γ_{31} : The effect of TXSCI (time for science) on the average African-American –science (IRT) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES and gender.

γ_{40} : The average Hispanic –science (IRT) regression slope across schools that represents the gap between Hispanic and Caucasian students, controlling for SES and gender.

γ_{41} : The effect of EQUIPM (frequency of science equipment use) on the average Hispanic –science (IRT) regression slope across schools that represents the gap between Hispanic and Caucasian students, controlling for SES and gender.

γ_{50} : The average Asian –science (IRT) regression slope across schools that represents the gap between Asian and Caucasian students, controlling for SES and gender.

γ_{51} : The effect of OFTSCI (frequency of science instructions) on the average Asian –science (IRT) regression slope across schools that represents the gap between Asian and Caucasian students, controlling for SES and gender.

γ_{60} : The average Others –science (IRT) regression slope across schools that represents the gap between Others and Caucasian students, controlling for SES and gender.

u_{0k}, u_{1k}, u_{2k}, u_{3k}, & u_{4k}: The unique increment to the intercept and slopes associated with school *k*.

Table 4.20

Effects of School – Level (First-grade) Characteristics on Children's Science (IRT) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Intercept, β_{0k}				
Overall mean achievement, γ_{00}	36.46^{**}	0.16	220.21	
Mean SES-achievement slope, β_{1k}				
Intercept, γ_{10}	2.68^{**}	0.14	18.47	
Mean Male-achievement slope, β_{2k}				
Intercept, γ_{20}	1.00^{**}	0.18	5.37	
Mean Afrc-Ame- achievement slope, β_{3k}				
Intercept, γ_{30}	-5.01^{**}	0.45	-10.97	
TXSCI, γ_{31}	1.62^{*}	0.87	1.86	
Mean Hispanic- achievement slope, β_{4k}				
Intercept, γ_{40}	-3.75^{**}	0.35	-10.73	
EQUIPM, γ_{41}	0.97^{*}	0.31	3.13	
Mean Asian achievement slope, β_{5k}				
Intercept, γ_{50}	-3.95^{**}	0.44	-8.87	
OFTSCI, γ_{51}	2.37^{**}	0.67	3.54	
Mean Others- achievement slope, β_{6k}				
Intercept, γ_{60}	-2.32^{**}	0.61	-3.75	
Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	3.00	72	145.70	0.001
SES slope, u_{1k}	0.92	72	105.68	0.006
Male slope, u_{2k}	1.47	72	117.21	0.001
Afrc-Ame slope, u_{3k}	13.46	71	92.63	0.043
Hispanic slope, u_{4k}	6.21	71	144.29	0.001
Student level error, r_{jk}	29.23			

Deviance = 35309.60 with 16 *df*

$^{*}p<0.05$, $^{**}p<0.001$

The results for the school model were similar to the results for the student model. The average school science (IRT) mean was 36.46, γ_{00}, (*se*= 0.16, *t*=220.21, *p*=<.001) for the reference student (Female=0, Caucasian=0, and with average SES status) (Table 4.20).

While children's SES level and gender were positively associated with the average school science (IRT) achievement, their race/ethnicity was negatively associated. On average as the students' SES level increased one unit, the science (IRT) achievement of children increased about γ_{10}=2.68 points (*se*= 0.14, *t*=18.47, *p*=<.001). In addition, students' gender was also significantly related γ_{20}=1.00 (*se*= 0.18, *t*=5.37, *p*=<.001) and indicated that male students' scores were one point higher than their female classmates within schools.

The effect of children's race/ethnicity revealed that on average the scores for African-American students 5.01 (*p*=<.001), Hispanic students 3.75 (*p*=<.001), Asian students 3.95 (*p*=<.001), and children from 'others' group 2.32 (*p*=<.001) were lower than Caucasian students science achievement scores. African-American children's IRT science scores increased as a function of 'time for science' (TXSCI) about 1.62 points (*se*= 0.87, *t*=1.86, *p*=<.05). Hispanic students' scores increased when they had more opportunities to use science equipment (EQUIPM) (γ_{41}=0.97, *se*= 0.31, *t*=3.13, *p*=<.05).

It was also found that Asian children's scores were positively associated with 'frequency of science instructions' (OFTSCI) (γ_{51}=2.37, *se*= 0.67, *t*=3.54, *p*=<.001), after controlling for time for science and frequency of science equipment use.

Table 4.20 reports test statistics of each of the variance components. The estimated variance among the means was 3.00 (χ^2=145.70, *df*=72, *p*=<.001). A range of plausible values for the school means was; $36.46 \pm 1.96\,(3)^{1/2}$ = (33.07, 39.85). The variance-explained statistics were calculated as 3%. This means that only 3% of the parameter variation in the means for school achievement was explained by school-level variables (TXSCI, EQUIPM, and OFTSCI). Deviance statistics for the current covariance components model was 35309.60 and the number of estimated parameters was 16.

First-Grade – ARS Results

Unconditional model.

$$Science(ARS)_{jk} = \beta_{0k} + r_{jk}$$

Where we assume r_{jk} ~ independently N (0, σ^2) for *j*=1,…, n_j students in school *k*, and k= 1,…, 570 schools. We refer to σ^2 as the student-level variance.

$$\beta_{0k} = \gamma_{00} + u_{0k}$$

Where we assume u_{0k} ~ independently N (0, τ_{00}). We refer to τ_{00} as the school level variance.

Table 4.21

Fully Unconditional Model of ARS Science Scores (First-grade)

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Average school mean, γ_{00}	3.34^{**}	0.02	143.58	

Random Effect	*Variance*	*df*	χ^2	*p-value*
School mean status, u_{0k}	0.17	569	1946.01	0.001
Level-1 Effect, r_{jk}	0.71			

Deviance = 14637.61 with 2 *df*

$^{**}p<0.001$

The weighted least square estimate for the grand mean science (ARS) scores in spring semester at the Kindergarten level was 3.34 (γ_{00}) with a standard error of 0.02 (*t*=143.58, *p*=<.001) yielding 95% confidence interval of 3.3-3.38. The second part of Table 4.21 lists restricted maximum likelihood estimates of the variance components. The expected student level variance was r_{jk}=0.71. There was significant variation among the schools (χ^2= 1946.01, *p*=<.001). The estimated variability in the school means was 0.17 (u_{0k}) and the *plausible values range* for these means were;

$$3.58 \pm 1.96\,(0.19)^{1/2} = (2.54, 4.14)$$

This suggests that there was substantial range of in average achievement levels (ARS) among schools in the sample. The proportion of variance between schools (*intraclass correlation*) was also estimated by substituting the estimated variance components for their respective parameters in following equation:

$$\tau_{00}/(\tau_{00}+\sigma^2)=0.19$$

This suggests that about 19% of the variance in science (ARS) achievement was between schools. Deviance for the unconditional model was 14637.61 with 2 estimated parameters (Table 4.21).

Student model.

<u>Level – 1 Model:</u>

$$Science(ARS)_{jk}=\beta_{0k}+\beta_{1k}(SES)+\beta_{2k}(Afrc-Ame)+r_{jk}$$

Where;

β_{0k} : Predicted Science (ARS) achievement for a student who is female, Caucasians and average on SES in school *k*th.

β_{1k} : The differentiating effect of social class (SES) in the *k*th school, after controlling the effects of individual student's gender and race/ethnicity.

β_{2k} : The adjusted mean difference between science achievements of African American students versus Caucasian students in the *k*th school after controlling the effects of individual student's SES, gender and other race/ethnicity groups.

r_{jk} : Unexplained residual variance at Level -1 after taking account into students' social status (SES), gender, and race/ethnicity.

<u>Level – 2 Model:</u>

$$\beta_{0k}=\gamma_{00}+u_{0k}$$
$$\beta_{1k}=\gamma_{10}+u_{1k}$$
$$\beta_{2k}=\gamma_{20}+u_{2k}$$

Table 4.22

Effects of Student – Level (First-grade) Characteristics on Children's Science (ARS) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Intercept, β_{0k}				
Overall mean achievement, γ_{00}	3.38^{**}	0.02	142.39	
Mean SES-achievement slope, β_{1k}				
Intercept, γ_{10}	0.29^{**}	0.02	13.14	
Mean Afrc-Ame -achievement slope, β_{2k}				
Intercept, γ_{20}	-0.18^{*}	0.06	-2.91	
Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	0.16	163	374.39	0.001
SES slope, u_{1k}	0.01	163	220.95	0.002
Afrc-Ame slope, u_{3k}	0.14	163	207.76	0.010
Student level error, r_{jk}	0.66			

Deviance = 14359.63 with 7 *df*

$*p<0.05$, $**p<0.001$

Table 4.22 reports the effects of student level variables on children's science (ARS) scores. The student level model results indicated that the average school (ARS) score mean was 3.38, γ_{00}, (*se*= 0.02, *t*=142.39, *p*=<.001) for the reference student. The reference student for the student model was Caucasian female student who had an average socioeconomic status (SES). The average SES-achievement slope was 0.29, γ_{10}, and the effect of SES on the estimated science (ARS) achievement was found to be statistically significant (*se*= 0.02, *t*=13.14, *p*=<.001). This means that a student with one standard deviation higher SES level scored 0.29 points higher than others. African-American students' science achievement on the ARS scale was 0.18, γ_{20}, points lower than Caucasian students (*se*= 0.06, *t*=-2.91, *p*=<.05) in school *k*.

The estimated variance among school means was 0.16 (u_{0k}) with related chi-statistics of 374.39 (*p*=<.001). The average SES-achievement slope was u_{1k} =0.01 (χ^2 =220.95, *p*=.002) and African-American-achievement slope was u_{3k} =0.14

(χ^2 =207.76, *p*=.010). The *plausible values range* for school means was (2.6, 4.16), for SES-achievement slope was (0.1, 0.48), and for African-American-achievement slope was (-0.9, 0.54). Additionally, adding SES, gender and race/ethnicity variables as predictors of science (ARS) achievement reduced the within-school variance by 7%. Deviance for the student model was 14359.63, and the number of estimated parameters was 7.

School model.

Level – 1 Model:

$$Science(ARS)_{jk} = \beta_{0k} + \beta_{1k}(SES) + \beta_{2k}(Afrc - Ame) + r_{jk}$$

Level – 2 Model:

$$\beta_{0k} = \gamma_{00} + u_{0k}$$
$$\beta_{1k} = \gamma_{10} + u_{1k}$$
$$\beta_{2k} = \gamma_{20} + \gamma_{21}(EQUIPM) + u_{2k}$$

Where;

γ_{00} : The average of the school means on science (ARS) achievement for Caucasian, females of average SES across the population of schools.

γ_{10} : The average SES-science (ARS) slope across schools that represents the predicted change in science (ARS) score for one unit change in SES, controlling for race/ethnicity.

γ_{20} : The average African-American–science (ARS) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES.

γ_{21} : The effect of CHCLDS (child-selected activities) on the average African-American –science (ARS) regression slope across schools that represents the gap between African-American and Caucasian students, controlling for SES.

u_{0k} , u_{1k} , &, u_{2k} : The unique increment to the intercept associated with school *k*.

Table 4.23

Effects of School – Level (First-grade) Characteristics on Children's Science (ARS) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*
Intercept, β_{0k}			
Overall mean achievement, γ_{00}	3.38^{**}	0.02	142.35
Mean SES-achievement slope, β_{1k}			
Intercept, γ_{10}	0.29^{**}	0.02	13.13
Mean Afrc-Ame -achievement slope, β_{2k}			
Intercept, γ_{20}	-0.18^{*}	0.06	-2.85
EQUIPM, γ_{21}	-0.09^{*}	0.04	-2.00

Random Effects	*Variance Component*	*df*	χ^2	*p value*
School – level error, u_{0k}	0.16	163	374.55	0.001
SES slope, u_{1k}	0.01	163	220.91	0.002
Afrc-Ame slope, u_{3k}	0.14	162	203.96	0.014
Student level error, r_{jk}	0.66			

Deviance = 14358.59 with 7 *df*

**p*<0.05, ***p*<0.001

The average school science (ARS) mean was 3.38, γ_{00}, (*se*= 0.02, *t*=142.35, *p*=<.001) for the reference student (Female=0, Caucasian=0, and with average SES status) (Table 4.23). The average SES-achievement slope was 0.29, γ_{10}, and the effect of SES on the estimated science (ARS) achievement was found to be statistically significant (*se*= 0.02, *t*=13.13, *p*=<.001). This means that a student with one standard deviation higher SES level scored 0.29 points higher than others. African-American students' science achievement on the ARS scale was 0.18, γ_{20}, points lower than Caucasian students (*se*= 0.06, *t*=-2.85, *p*=<.05) in school *k*.

The effect of frequency of science equipment use (EQUIPM) on African-American students' science (ARS) scores was negative but statistically significant (γ_{21}=-0.09 (*se*= 0.04, *t*=-2.00, *p*=<.05) meaning that African-American children's science (ARS) scores decreased when they were given more time to use science equipment.

Table 4.23 also includes the test statistics for each of the variance components. The estimated variance among school means was 0.16, u_{0k}, (χ^2=374.55, *df*=163, *p*=<.001). The *plausible values range* for school means was (2.6, 4.16), for the SES-achievement slope was (0.1, 0.48), and for African-American-achievement slope was (-0.9, 0.54). Adding level-3 variables as predictors of science (ARS) achievement did not affect the within-school variance. School level variance, u_{0k}, remained to be same, 016. Deviance for the student model was 14358.59, and the number of estimated parameters was 7.

Results of Three-Level Hierarchical Linear Growth Modeling

Table 4.24

Descriptive Statistics for Longitudinal Science IRT & ARS Score Analysis

Variables	N	Mean	SD	Minimum	Maximum
		Level – 1			
Science (IRT)	15008	24.76	7.80	7.30	48.44
Science (ARS)	15008	3.18	1.08	1.00	5.00
Time	15008	0.50	0.50	0.00	1.00
		Level – 2			
SES	7507	0.05	0.67	-0.99	2.67
Afrc-Ame	7507	0.15	0.36	0.00	1.00
Hispanic	7507	0.13	0.33	0.00	1.00
Asian	7507	0.05	0.21	0.00	1.00
Others	7507	0.06	0.24	0.00	1.00
Male	7507	0.50	0.50	0.00	1.00
		Level – 3			
CHCLDS	611	2.69	0.61	1.00	5.00
OFTSCI	611	3.54	0.68	2.00	5.00
TXSCI	611	1.32	0.40	1.00	3.00
EQUIPM	611	3.74	1.19	0.00	6.00

Note. N=Sample size; SD= Standard deviation.

The Longitudinal Kindergarten science sample consisted of 7507 student nested within 611 schools. 49.7% of the sample was female (N=3729). The majority of the participants were Caucasian (60.9%) followed by African-American (15.5%), Hispanic

(12.7%), Others (includes Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) (6.3%), and Asian (4.6%).

Descriptive statistics included the full range of possible variation in IRT scores (7.30 to 48.44) and ARS scores (1.00 to 5.00) for the Kindergarten data included in the HLM analysis. For this data set, the mean IRT science score was 24.76 and the mean ARS science score was 3.18. Distribution of children's SES in kindergarten level ranged between -0.99 and 2.67. Table 4.24 reports the sample sizes (*n)*, means and standard deviation values for all student and school variables used in this study's three-level HLM modeling.

Table 4.25
Longitudinal Science IRT and ARS Scores by Gender

	Fall kindergarten				Spring Kindergarten			
	IRT		ARS		IRT		ARS	
	M	SD	M	SD	M	SD	M	SD
Male	22.48	7.34	2.63	0.98	27.67	7.63	3.58	0.95
Female	22.04	7.00	2.74	0.97	27.22	7.30	3.72	0.92
Total	22.27	7.18	2.69	0.98	27.45	7.47	3.65	0.94

Note. M=Mean; SD= Standard deviation.

Both IRT and ARS science scores on science achievement by gender are presented in Table 4.25. The average science IRT score in fall was 22.27 (SD=7.18) and in spring kindergarten 27.45 (SD=7.47), respectively. The average science ARS score in fall was 2.69 (SD=0.98), and 3.65 (SD=0.94) in spring. The results suggest that male students' consistently outperformed their female classmates on the IRT scales (Cohen's Effect Size, d=0.11). The ARS scale, however, indicate that female students outperformed male students (Cohen's Effect Size, d=0.06) (Table 4.25).

Pearson Product correlations between science measures, SES, and Level – 3 variables at fall and spring are presented in Table 4.26. Fall and spring science IRT scale scores were found to be significantly correlated (r=.850). SES and fall and spring science IRT scale scores were moderately related (r = .440 and r = 438, respectively). When SES level increased, students' IRT science scores also increased. There was a significant correlation between students' ARS science scores and SES ($r_{fallARS}$ = .280 and $r_{springARS}$=.255).

Table 4.26

Correlations among Outcome Measures and Level – 3 Variables (Longitudinal)

	Fall IRT	Spring IRT	Fall ARS	Spring ARS	CHCLDS	OFTSCI	TXSCI	EQUIPM	SES
Fall IRT	1.00								
Spring IRT	.850**	1.00							
Fall ARS	.404**	.401**	1.00						
SpringARS	.410**	.428**	.580**	1.00					
CHCLDS	-014**	-011**	.012**	.037**	1.00				
OFTSCI	-010**	.001	.019**	.068**	.188**	1.00			
TXSCI	-022**	-020**	.033**	.044**	.121**	.259**	1.00		
EQUIPM	.035**	.040**	.017**	.051**	.217**	.278**	.127**	1.00	
SES	.440**	.438**	.280**	.255**	.004**	-015**	-040**	.069**	1.00

Note 1. ** Correlation is significant at the 0.01 level (2-tailed).

Note 2. Correlations were computed using weighting variable BYCW0.

Longitudinal IRT Data

Linear growth model.

Level – 1 Model:

$$Science(IRT)_{ijk} = \pi_{0jk} + \pi_{1jk}(Time_{ijk}) + e_{ijk}$$

Where;

$Science(IRT)_{ijk}$: Outcome (Science - IRT) at a time *i* for student *j* in school *k*;

π_{0jk} : (intercept) Predicted science achievement for *j*th student in school *k* (initial status of student jk – Fall Kindergarten)

π_{1jk} : Predicted change of science achievement per time for student *j* in school *k* (individual – specific rate of change)

$Time_{ijk}$: Time characteristics that predict outcome (Science) (Fall Kindergarten: 0 and Spring Kindergarten: 1)

e_{ijk} : With-in person deviation, after controlling for Time, assumed to be N $(0, \sigma^2)$;

Level – 2 Model:

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$
$$\pi_{1jk} = \beta_{10k}$$

Level – 3 Model:

$$\beta_{00k} = \gamma_{000} + u_{00k}$$
$$\beta_{10k} = \gamma_{100} + u_{10k}$$

Table 4.27

Longitudinal Linear Model of Growth in Science (IRT) Knowledge (Fully Unconditional Model)

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Mean initial status, γ_{000}	21.88	0.16	129.32	
Mean growth rate, γ_{100}	5.15	0.07	72.62	
Random Effect	*Variance*	*df*	χ^2	*p-value*
Level – 1 Variance				
Temporal variation, e_{ijk}	7.51			
Level – 2 (student within schools)				
Individual initial status, r_{0jk}	33.23	6896	67898.23	0.001
Level – 3 (between schools)				
School mean status, u_{00k}	12.32	610	2811.35	0.001
School mean learning rate, u_{10k}	1.19	610	1198.16	0.001
Deviance = 91394.21 with 7 *df*				
Reliability Estimate				
Initial status, π_{0jk}	0.756			
Growth rate, π_{1jk}	0.469			

The linear growth model results included a significant linear term with nonzero initial status level. The estimated mean intercept, γ_{000}, was 21.88 (*se*=0.16, *p*<.001), with the average science learning rate, based on the IRT scale score within two semesters from fall to spring kindergarten, was γ_{100}, 5.15 (*se* =0.07, *p*<.001). This means that over time children's science scores on the IRT scales increased. The average science IRT score at the first testing (fall) was estimated to be 21.88 with a standard error of 0.16 (*p*<.001) yielding a 95% confidence interval of (21.56; 22.19). The χ^2 statistics accompanying the variance components suggest that there was significant variation among children within schools in terms of initial status and learning rates (i.e., π_{0jk} and π_{1jk}). There was also significant variation between schools for mean initial status and mean learning rates (i.e., β_{00k} and β_{10k}). The variation between students within schools (χ^2 = 67898.23, *df*= 6896, *p*<.001) and between schools (χ^2 = 2811.35, *df*= 610, *p*<.001) were statistically significant suggesting that students and schools differ in levels of science (IRT) achievement. Based on the variance component estimates, the following formula was used to define variance partitioning that lies between schools for both initial status and growth rate:

$$\pi_{pjk} = \frac{\tau_{\beta pp}}{\tau_{\beta pp} + \tau_{\pi pp}} =$$

$$= 12.32/(12.32 + 33.23) = 12.32/45.55 = .27$$

$$= 1.19(1.19 + 33.23) = 1.19/34.42 = .04$$

Therefore, the results suggest that 27% of residual variation in science achievement, based on the IRT scale scores, was between schools. The result for growth rates was only 4%. Deviance for the covariance component model was 91394.21, and the number of estimated parameters was 7 (Table 2.27).

Student model.

In the student model, student level variables were added into the model to estimate the effects of student characteristics on children's science scores based on their IRT scale scores. Basically, the Level – 2 model represents the proportion of variance between students (at level 2) within Level – 3 units (schools). Based on the linear growth model results, the random effect of growth rates among students was fixed at zero in the second level. The third level of the model remained the same, and did not include any Level – 3 variables. Again, based on previous model's results, random effects of mean science (IRT) achievement, the mean SES between schools and the mean growth rate again between schools were freely estimated, but the remaining random effects were fixed at zero.

Level – 1 Model:

$$Science(IRT)_{ijk} = \pi_{0jk} + \pi_{1jk}(Time_{ijk}) + e_{ijk}$$

Level – 2 Model:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}(SES) + \beta_{02k}(Afrc - Ame) + \beta_{03k}(Hispanic) + \beta_{04k}(Asian) + \beta_{05k}(Others) + \beta_{06k}(Male) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k} + \beta_{11k}(Afrc - Ame)$$

Where;

β_{00k} : Estimated mean science achievement for a typical student within school *k* (final typical student achievement)

β_{01k} : The effect of socioeconomic status on science achievement in school *k* controlling for male and race/ethnicity.

β_{02k} : Difference between African-American vs. Caucasians on mean science achievement in

school *k* controlling for male, socioeconomic status.

β_{03k} : Difference between Hispanic vs. Caucasians on mean science achievement in school *k* controlling for male, socioeconomic status.

β_{04k} : Difference between Asian vs. Caucasians on mean science achievement in school *k* controlling for male, socioeconomic status.

β_{05k} : Difference between Others vs. Caucasians on mean science achievement in school *k* controlling for male, socioeconomic status.

β_{06k} : The effect of Male on science achievement in school *k* controlling for male, socioeconomic status and race/ethnicity.

β_{10k} : Predicted mean science achievement growth rate of the child who is Caucasians, male and average on socioeconomic level in school *k*.

β_{11k} : African-American students mean growth rate slope on science achievement in school *k*

r_{0jk} : Variance of science final scores within schools.

<u>*Level – 3 Model:*</u>

$$\beta_{00k} = \gamma_{000} + u_{00k}$$
$$\beta_{01k} = \gamma_{010} + u_{01k}$$
$$\beta_{02k} = \gamma_{020}$$
$$\beta_{03k} = \gamma_{030}$$
$$\beta_{04k} = \gamma_{040}$$
$$\beta_{05k} = \gamma_{050}$$
$$\beta_{06k} = \gamma_{060}$$
$$\beta_{10k} = \gamma_{100} + u_{10k}$$
$$\beta_{11k} = \gamma_{110}$$

The reference student for the student model referred to Caucasian student who was female and average with respect to socioeconomic status. Conditional Level – 2 model results indicated that mean score, race effects, growth rates, and race effects on growth show nonzero effects. Estimated mean science (IRT) achievement for an average individual (Caucasian, female, and average in SES) was 23.44 (*se* =0.13, *t*=173.00, *p*<.001). The effect of SES on the IRT science scores for an individual was found to be 3.78 (γ_{010}). That is, a student with one standard deviation higher SES level had a mean science score that was 3.78 points higher than others (*t*=29.81, *p*<.001). Additionally, mean scores were lower for African – American (γ_{020}=-4.64, *se* =0.24, *t*=-19.01, *p*<.001), Hispanic (γ_{030}=-3.08, *se* =0.25, *t*=-12.19, *p*<.001), and Asian (γ_{040}=-4.61, *se* =0.41, *t*=-11.09, *p*<.001) students as compared to Caucasian students. This means that African – American students' scores were 4.64 points, Hispanic students' 3.08 points, and Asian students' 4.61 points lower than their Caucasian counterparts within classroom *k*. Moreover, students from the others race group (Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) had scores 2.73 points (*se* =0.37, *t*=-7.32, *p*<.001) lower than Caucasian children within classroom *k*. Within-classroom effects of Male on science (IRT) scores showed that male students had scores 0.37 (*se* =0.15, *t*=2.48, *p*<.05) point higher than their female classmates, after controlling for other within student characteristics (Table 4.28).

Table 4.28

Longitudinal Effects of Student – Level Characteristics on Children's Science (IRT) Scores

Fixed Effect	*Coefficient*	*Se*	*t ratio*
Model for initial status, π_{0jk}			
Mean status of a typical child, β_{00k}			
Intercept, γ_{000}	23.44^{**}	0.13	173.00
Model for SES, β_{01k}			
Intercept, γ_{010}	3.78^{**}	0.12	29.81
Model for African–American, β_{02k}			
Intercept, γ_{020}	-4.64^{**}	0.24	-19.01
Model for Hispanic, β_{03k}			
Intercept, γ_{030}	-3.08^{**}	0.25	-12.19
Model for Asian, β_{04k}			
Intercept, γ_{040}	-4.61^{**}	0.41	-11.09
Model for Others, β_{05k}			
Intercept, γ_{050}	-2.73^{**}	0.37	-7.32
Model for Male, β_{06k}			
Intercept, γ_{060}	0.37^{*}	0.15	2.48
Growth rate, π_{1jk}			
Mean growth rate of a typical child, β_{10k}			
Intercept, γ_{100}	5.27^{**}	0.07	75.16
Mean growth rate for African-American, β_{11k}			
Intercept, γ_{110}	-0.64^{**}	0.14	-4.56

**p*<0.05, ***p*<0.001

Overall mean growth rate of science (IRT) achievement during the kindergarten year was 5.27 (*se* =0.07, *t*=75.16, *p*<.001). This means that from fall to spring semesters at the kindergarten level, Caucasian children's science scores, based on the IRT scales, increased by 5.27 points. African – American students had lover growth rate than Caucasian students -0.64 (*se* =0.14, *t*=-4.56, *p*<.001) (see Table 4.28).

Table 4.29

Variance Components from Selected Student Model on Children's Science Learning (IRT) (Longitudinal)

Random Effect	*Variance*	*df*	χ^2	*p-value*
Level – 1 Variance				
Temporal variation, e_{ijk}	7.50			
Level – 2 (student within schools)				
Individual initial status, r_{0jk}	28.22	6281	53173.02	0.001
Level – 3 (between schools)				
School mean status, u_{00k}	2.27	609	1038.01	0.004
School mean status/SES, u_{01k}	0.68	609	705.66	0.001
School mean learning rate, u_{10k}	1.13	609	1172.76	0.001

Deviance = 89738.82 with 17 *df*

The χ^2 statistics accompanying the variance components indicated that the residual parameter variances remained unexplained (Table 4.29). The variations within students, between students within schools, and between schools were statistically significant (*p*=.001). This suggests that students and schools differ in levels of science (IRT) achievement. Deviance for the covariance component model was 89738.82 and the number of estimated parameters was 17.

School model.

Level – 1 Model:

$$Science(IRT)_{ijk} = \pi_{0jk} + \pi_{1jk}(Time_{ijk}) + e_{ijk}$$

Level – 2 Model:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}(SES) + \beta_{02k}(Afrc - Ame) + \beta_{03k}(Hispanic) + \beta_{04k}(Others) + \beta_{05k}(Male) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k}$$

Level – 3 Model:

$$\beta_{00k} = \gamma_{000} + u_{00k}$$
$$\beta_{01k} = \gamma_{010} + \gamma_{011}(CHCLDS) + \gamma_{012}(TXSCI) + u_{01k}$$
$$\beta_{02k} = \gamma_{020}$$
$$\beta_{03k} = \gamma_{030}$$
$$\beta_{04k} = \gamma_{040}$$
$$\beta_{05k} = \gamma_{050} + \gamma_{051}(CHCLDS) + \gamma_{052}(OFTSCI)$$
$$\beta_{06k} = \gamma_{060}$$
$$\beta_{10k} = \gamma_{100} + u_{10k}$$
$$\beta_{11k} = \gamma_{110}$$

Where;

γ_{000} : Estimate of mean initial status on science in a linear growth model for a typical student (Caucasians, female, average respect to SES)

γ_{010} : The effect of SES in science achievement in school *k* controlling for race/ethnicity and gender.

γ_{011} : The effect of child selected activities on SES gap in science achievement in school *k* controlling for race/ethnicity and gender.

γ_{012} : The effect of time for science on SES gap in science achievement in school *k* controlling for race/ethnicity and gender.

γ_{020} : Mean African-American – Caucasians gap in science in school *k* controlling for SES, Asian, Hispanic, Others and gender.

γ_{030} : Mean Hispanic – Caucasians gap in science in school *k* controlling for SES, Asian, African-American, Others and male.

γ_{040} : Mean Asian – Caucasians gap in science in school *k* controlling for SES, African-American, Hispanic, Others and gender.

γ_{050} : Mean Others – Caucasians gap in science in school *k* controlling for SES, African-American, Hispanic, Asian and gender.

γ_{051} : The effect of child selected activities on Others - Caucasians gap in science achievement in school *k* controlling for SES, African-American, Hispanic, Asian and gender.

γ_{052} : The effect of frequency of science instructions on Others - Caucasians gap in science achievement in school *k* controlling for SES, African-American, Hispanic, Asian and gender.

γ_{060} : Mean male – female gap in science in school *k* controlling for SES, African-American, Hispanic, Asian and Others.

γ_{100} : Estimate of mean growth rate on science achievement for a typical student (Caucasians, female, average respect to SES).

γ_{110} : African-American – Caucasians gap in estimate of mean growth rate in science achievement in school *k*.

u_{01k} & u_{10k} : Deviation of science achievement from its predicted value.

The reference student for the school model referred to Caucasian student who was female and average with respect to socioeconomic status nested within a school. The predicted mean science (IRT) achievement for the typical student was found to be 23.45 (*se* =0.13, *t*=173.00, *p*<.001). The effect of SES on the IRT scale science scores for an individual was found to be 3.78 (γ_{010}). That is, a student with one standard deviation higher SES level had a mean science score 3.78 points higher than others. Higher SES students' initial science (IRT) scores increased (0.46 points) as a function of more child selected activities (γ_{011}=0.46, *se* =0.20, *t*=2.25, *p*<.05). Their scores also and increased (0.63 points) as a function of more (longer) time engaged in classroom science activities (γ_{012}=0.63, *se* =0.29, *t*=2.16, *p*<.05). African – American, Hispanic, and Asian students started out an average of 4.64 (γ_{020}=-4.64, *se* =0.24, *t*=-18.89, *p*<.001), 3.09 (γ_{030}=-3.09, *se* =0.25, *t*=-12.22, *p*<.001), and 4.62 (γ_{040}=-4.62, *se* =0.41, *t*=-11.11, *p*<.001), points behind their Caucasian peers (see Table 4.30).

Table 4.30

Longitudinal Effects of School – Level Characteristics on Children's Science (IRT) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*
Model for initial status, π_{0jk}			
Mean status of a typical child, β_{00k}			
Intercept, γ_{000}	23.45**	0.13	173.00
Model for SES, β_{01k}			
Intercept, γ_{010}	3.78**	0.12	30.47
CHCLDS, γ_{011}	0.46*	0.20	2.25
TXSCI, γ_{012}	0.63*	0.29	2.16
Model for African–American, β_{02k}			
Intercept, γ_{020}	-4.64**	0.24	-18.89
Model for Hispanic, β_{03k}			
Intercept, γ_{030}	-3.09**	0.25	-12.22
Model for Asian, β_{04k}			
Intercept, γ_{040}	-4.62**	0.41	-11.11
Model for Others, β_{05k}			
Intercept, γ_{050}	-2.71**	0.34	-7.93
CHCLDS, γ_{051}	-2.13**	0.52	-4.03
OFTSCI, γ_{052}	1.11*	0.49	2.27
Model for Male, β_{06k}			
Intercept, γ_{060}	0.38*	0.15	2.57
Growth rate, π_{1jk}			
Mean growth rate of a typical child, β_{10k}			
Intercept, γ_{100}	5.27**	0.07	75.19
Mean growth rate for African-American, β_{11k}			
Intercept, γ_{110}	-0.64**	0.14	-4.56

*$p<0.05$, **$p<0.001$

Students from *Others* group had initial science (IRT) scores 2.71 points lower than Caucasian children within classroom *k* (γ_{050}=-2.71, *se* =0.34, *t*=-7.93, $p<.001$). Their initial science scores decreased as a function of "child-centered activities" (γ_{051}=-2.13, *se*=0.34, *t*=-4.03, *p*<.001). Interestingly, this group's scores were 1.11 points higher when they had more of an opportunity to use science equipment (frequency use of science equipment) (γ_{052}=1.11, *se* =0.49, *t*=2.27, *p*<.05). Male students had higher science (IRT) scores than their female classmates (γ_{060}=0.38, *se* =0.15, *t*=2.57, *p*<.05). The predicted overall mean growth rate for an advantaged child was 5.27 (*se* =0.07, *t*=75.19, *p*<.001). On average, such children gained about 5.27 points from fall to spring semesters at the kindergarten level. African – American children's learning rate, however, was 0.64 points lower than Caucasian children (*se* =0.14, *t*=-4.56, *p*<.001). These results are summarized in the Table 4.30.

Table 4.31 represents estimated variances and related χ^2 statistics from the three – level decomposition. These results suggested that the residual parameter variance is unexplained in π_{0jk}, β_{00k}, and β_{10k}. Deviance for the covariance component model was 9710.82 and the number of estimated parameters was 21.

Table 4.31

Variance Components from Selected School Model on Children's Science Learning (IRT) (Longitudinal)

Random Effect	*Variance*	*df*	χ^2	*p-value*
Level – 1 Variance				
Temporal variation, e_{ijk}	7.50			
Level – 2 (student within schools)				
Individual initial status, r_{0jk}	28.22	6282	53127.08	0.001
Level – 3 (between schools)				
School mean status, u_{00k}	2.16	608	1023.20	0.001
School mean status/SES, u_{01k}	0.52	606	696.25	0.006
School mean learning rate, u_{10k}	1.13	608	1170.21	0.001

Deviance = 89710.28 with 21 *df*

Longitudinal ARS Data

Linear growth model.

Level – 1 Model:

$$Science(ARS)_{ijk} = \pi_{0jk} + \pi_{1jk}(Time_{ijk}) + e_{ijk}$$

Outcome (Science - ARS) at a time *i* for student *j* in school *k*;

Where;

π_{0jk} : (intercept) Predicted science achievement for *j*th student in school *k* (initial status of student *jk* – Fall Kindergarten)

π_{1jk} : Predicted change of science achievement per time for student *j* in school *k* (individual – specific rate of change)

$Time_{ijk}$: Time characteristics that predict outcome (Science) (Fall Kindergarten: 0 and Spring Kindergarten: 1)

e_{ijk} : With-in person deviation, after controlling for Time, assumed to be N $(0, \sigma^2)$;

Level – 2 Model:

$$\pi_{0jk} = \beta_{00k} + r_{ojk}$$
$$\pi_{1jk} = \beta_{10k}$$

Level – 3 Model:

$$\beta_{00k} = \gamma_{000} + u_{00k}$$
$$\beta_{10k} = \gamma_{100} + u_{10k}$$

The linear growth model results (Table 4.32) yielded a significant linear term with a nonzero initial status level. The estimated mean intercept, γ_{000}, was 2.65 (*se*=0.02, *t*=103.65, *p*<.001). The average science learning rate based on the ARS scale score from fall to spring kindergarten was, γ_{100}, 0.97 (*se* =0.02, *t*=47.43, *p*<.001), indicating that over time (from fall to spring semester in kindergarten level) children's science scores on the ARS scales increased. The average science ARS score at the first testing was estimated to be 2.65 with a standard error of 0.02 (*p*<.001) yielding a 95% confidence interval of (2.61; 2.68). The χ^2 statistics accompanying the variance components showed that there was significant variation between children within schools for initial status and learning rates (i.e., π_{0jk} and π_{1jk}), and significant variation between schools for mean initial status and mean learning rates (i.e., β_{00k} and β_{10k}). The variation between students within schools (χ^2 = 24572.23, *df*= 6896, *p*<.001), and between schools (χ^2 = 3944.44, *df*= 610, *p*<.001) was statistically significant; indicating that students' science achievement (ARS) differs.

Table 4.32

Longitudinal Linear Model of Growth in Science (ARS) Knowledge (Fully Unconditional Model)

Fixed Effect	*Coefficient*	*se*	*t ratio*	
Mean initial status, γ_{000}	2.65	0.02	103.65	
Mean growth rate, γ_{100}	0.97	0.02	47.43	
Random Effect	*Variance*	*df*	χ^2	*p-value*
Level – 1 Variance				
Temporal variation, e_{ijk}	0.29			
Level – 2 (student within schools)				
Individual initial status, r_{0jk}	0.38	6896	24572.23	0.001
Level – 3 (between schools)				
School mean status, u_{00k}	0.29	610	3944.44	0.001
School mean learning rate, u_{10k}	0.18	610	2950.55	0.001
Deviance = 35873.77 with 7 *df*				
Reliability Estimate				
Initial status, π_{0jk}	0.814			
Growth rate, π_{1jk}	0.762			

Based on the variance component estimates, the percentage of variation that lies between schools, for both initial status and growth rate, yielded the following results:

$$\pi_{pjk} = \frac{\tau_{\beta pp}}{\tau_{\beta pp} + \tau_{\pi pp}} =$$

$$= 0.29/(0.29 + 0.38) = 0.29/0.67 = .43$$

$$= 0.18/(0.18 + 0.38) = 0.18/0.56 = .32$$

The results suggest that 43% of residual variation in science achievement, based on ARS scale scores, was between schools. The variation between schools' growth rate was 32%. Deviance for the covariance component model was 35873.77, and the number of estimated parameters was 7.

Student model.

In the student model, student level variables were added into the model to estimate the effects of student characteristics on children's science scores, based on their ARS scale scores. Based on unconditional linear growth model results, the random effect of growth rates among students was fixed at zero within the second level. The third level of the model remained the same and it did not include any Level – 3 variables. Again, based on the previous model's results, random effects of mean science (ARS) achievement, and the mean growth rate between schools, were freely estimated with the remaining random effects fixed at zero.

Level – 1 Model:

$$Science(ARS)_{ijk} = \pi_{0jk} + \pi_{1jk}(Time_{ijk}) + e_{ijk}$$

Level – 2 Model:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}(SES) + \beta_{02k}(Afrc - Ame) + \beta_{03k}(Hispanic) + \beta_{04k}(Others) + \beta_{05k}(Male) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k}$$

Level – 3 Model:

$$\beta_{00k} = \gamma_{000} + u_{00k}$$

$$\beta_{01k} = \gamma_{010}$$

$$\beta_{02k} = \gamma_{020}$$

$$\beta_{03k} = \gamma_{030}$$

$$\beta_{04k} = \gamma_{040}$$

$$\beta_{05k} = \gamma_{050}$$

$$\beta_{10k} = \gamma_{100} + u_{10k}$$

The reference student for the student model referred to Caucasian student who was female and average with respect to socioeconomic status. The conditional Level -2 model results indicated that there were nonzero effects, on average, of mean score, race effects, growth rates, and race effect on growth.

Table 4.33

Longitudinal Effects of Student – Level Characteristics on Children's Science (ARS) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*
Model for initial status, π_{0jk}			
Mean status of a typical child, β_{00k}			
Intercept, γ_{000}	2.80^{**}	0.02	100.02
Model for SES, β_{01k}			
Intercept, γ_{010}	0.34^{**}	0.01	19.89
Model for African–American, β_{02k}			
Intercept, γ_{020}	-0.23^{**}	0.03	-7.13
Model for Hispanic, β_{03k}			
Intercept, γ_{030}	-0.17^{**}	0.03	-4.62
Model for Others, β_{04k}			
Intercept, γ_{040}	-0.15^{**}	0.04	-3.12
Model for Male, β_{05k}			
Intercept, γ_{050}	-0.12^{**}	0.01	-7.05
Growth rate, π_{1jk}			
Mean growth rate of a typical child, β_{10k}			
Intercept, γ_{100}	0.97^{**}	0.02	47.38

$^{**}p<0.01$

The estimated mean science (ARS) achievement for an individual who was average with respect to student predictors (Caucasian, female, and average in SES) was 2.80 (*se*=0.02, *t*=100.02, *p*<.001). The effect of SES on the ARS science scores for an individual was found to be 0.34 (γ_{010}). That is, a student with one standard deviation higher SES level had a mean science score that was .34 points higher than others. Additionally, mean scores were lower for African – American (γ_{020}=-0.23, *se* =0.03, *t*=-7.13, *p*<.001), Hispanic (γ_{030}=-0.17, *se* =0.03, *t*=-4.62, *p*<.001), and Others (Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children) (γ_{040}=-0.15, *se* =0.04, *t*=-3.12, *p*<.001) in comparison to Caucasian students. This means that African – American students' scores were 0.23 points, Hispanic students' 0.17 points, and Others students' 0.15 points, lower than their Caucasian counterparts within school *k*. Within-classroom effect of Male on science (ARS) scores showed that male students had scores that were 0.12 (*se* =0.01, *t*=-7.05, *p*<.001) point lower than their female peers' scores, after controlling other within student characteristics. Overall mean growth rate of science (ARS) achievement during the kindergarten year was 0.97 (*se* =0.02, *t*=47.38, *p*<.001). This means that from fall to spring semester, at the kindergarten level, a typical child's science achievement score increased by 0.97 points (Table 4.33).

The χ^2 statistics accompanying variance components indicated that residual parameter variances remained unexplained (Table 4.34). The variations within students, between students within schools, and between schools were statistically significant (*p*=.001); thus students and schools differ in levels of science (ARS) achievement. Deviance for the covariance component model was 35128.59, and the number of estimated parameters was 12.

Table 4.34

Variance Components from Selected Student Model on Children's Science Learning (ARS) (Longitudinal))

Random Effect	*Variance*	*df*	χ^2	*p-value*
Level – 1 Variance				
Temporal variation, e_{ijk}	0.29			
Level – 2 (student within schools)				
Individual initial status, r_{0jk}	0.33	6891	22364.57	0.001
Level – 3 (between schools)				
School mean status, u_{00k}	0.25	610	3663.15	0.001
School mean learning rate, u_{10k}	0.18	610	2950.26	0.001

Deviance = 35128.59 with 12 *df*

School model.

For this model, school model variables were added into the model to examine the effects of school model variables on students' science (ARS) performance.

Level – 1 Model:

$$Science(ARS)_{ijk} = \pi_{0jk} + \pi_{1jk}(Time_{ijk}) + e_{ijk}$$

Level – 2 Model:

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}(SES) + \beta_{02k}(Afrc - Ame) + \beta_{03k}(Hispanic) + \beta_{04k}(Others) + \beta_{05k}(Male) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k}$$

Level – 3 Model:

$$\beta_{00k} = \gamma_{000} + u_{00k}$$

$$\beta_{01k} = \gamma_{010} + \gamma_{011}(CHCLDS)$$

$$\beta_{02k} = \gamma_{020} + \gamma_{021}(TXSCI)$$

$$\beta_{03k} = \gamma_{030} + \gamma_{031}(TXSCI)$$

$$\beta_{04k} = \gamma_{040}$$

$$\beta_{05k} = \gamma_{050}$$

$$\beta_{10k} = \gamma_{100} + u_{10k}$$

The reference student for the school model referred to a Caucasian student who was female, and average with respect to socioeconomic status nested within a school. The predicted mean science (ARS) achievement for the typical student was found to be 2.80 (*se* =0.02, *t*=99.89, $p<.001$). The effect of SES on the ARS scale science scores for an individual was found to be 0.34 (γ_{010}). That is, a student with one standard deviation higher SES level had a mean science score that was 0.34 points higher than others (*se* =0.01, $p<.001$). Higher SES students' initial science (ARS) scores (0.05 points) increased as a function of participating in more child selected activities (γ_{011}=0.05, *se* =0.02, *t*=1.94, $p<.05$).

African – American, Hispanic, and Others students started out an average of 0.24 (γ_{020}=-0.24, *se* =0.03, *t*=-7.34, $p<.001$), 0.17 (γ_{030}=-0.17, *se* =0.03, *t*=-4.62, $p<.001$), and 0.15 (γ_{040}=-0.15, *se* =0.04, *t*=-3.06, $p<.05$), points behind Caucasian students. African-American and Hispanic students' science (ARS) scores increased .15 points as a function of more (longer) time engaged science activities (γ_{021}=0.15, $p<.001$ and γ_{031}=0.15, $p<.05$). Male students had lower scores (.12 points) than their female classmates (γ_{050}=-0.12, $p<.001$).

Table 4.35

Longitudinal Effects of School – Level Characteristics on Children's Science (ARS) Scores

Fixed Effect	*Coefficient*	*se*	*t ratio*
Model for initial status, π_{0jk}			
Mean status of a typical child, β_{00k}			
Intercept, γ_{000}	2.80^{**}	0.02	99.89
Model for SES, β_{01k}			
Intercept, γ_{010}	0.34^{**}	0.01	20.04
CHCLDS, γ_{011}	0.05^{*}	0.02	1.94
Model for African–American, β_{02k}			
Intercept, γ_{020}	-0.24^{**}	0.03	-7.34
TXSCI, γ_{021}	0.15^{**}	0.07	2.01
Model for Hispanic, β_{03k}			
Intercept, γ_{030}	-0.17^{**}	0.03	-4.62
TXSCI, γ_{031}	0.15^{*}	0.08	1.92
Model for Others, β_{04k}			
Intercept, γ_{040}	-0.15^{*}	0.04	-3.06
Model for Male, β_{05k}			
Intercept, γ_{050}	-0.12^{**}	0.01	-7.03
Growth rate, π_{1jk}			
Mean growth rate of a typical child, β_{10k}			
Intercept, γ_{100}	0.97^{**}	0.02	47.38

$^{*}p<0.05$, $^{**}p<0.01$

The predicted overall mean growth rate for an advantaged child was 0.97 (*se* =0.02, *t*=47.38, *p*<.001). On average, such children gained about 0.97 points from fall to spring semesters at the kindergarten level. These results are summarized in Table 4.35.

Table 4.36 reports the estimated variances and related χ^2 statistics from the three-level decomposition. These results suggest that residual parameter variance remains unexplained in π_{0jk}, β_{00k}, and β_{10k}. Deviance for the covariance components was 35115.79 and the number of estimated parameters was 15.

Table 4.36

Variance Components from Selected School Model on Children's Science Learning (ARS) (Longitudinal)

Random Effect	*Variance*	*df*	χ^2	*p-value*
Level – 1 Variance				
Temporal variation, e_{ijk}	0.29			
Level – 2 (student within schools)				
Individual initial status, r_{0jk}	0.33	6891	22329.24	0.001
Level – 3 (between schools)				
School mean status, u_{00k}	0.25	610	3674.95	0.001
School mean learning rate, u_{10k}	0.18	610	2950.25	0.001

Deviance = 35115.79 with 15 *df*

CHAPTER V

DISCUSSION

In this chapter, a summary of the current study including the research questions, the rationale for the study, the research method that was employed, and the major findings are summarized. Then, the major findings are discussed, for both the IRT and ARS science achievement scores and with reference to children's SES, gender, race/ethnicity, as well as the school level variables. Next, based on the results, policy and practical implementations, and recommendations for future research are presented. The final section summarizes the major conclusions.

Worldwide interest in teaching and learning science in early grades has provided some evidence that early science learning not only helps children to form their ideas, but also science teaching in the early grades offers the potential for addressing and modifying children's ideas, long before they enter higher grades (Davies & Ward, 2003; Harlen, 2001; Ravanis, 2004). Science, however, has been given minimal attention in early childhood classrooms (Dickinson, Burns, Hagen, & Locker, 1997; Johnson, 1999). Consequently, children's success in science has been an area of concern for many years for educators and policymakers (Johnson, 1999).

Many organizations and projects have influenced today's science teaching and learning in the early grades. One influential report was Project 2061 by the American Association for the Advancement of Science (AAAS, 1998). Through this report the AAAS sought to develop a vision for science education in order to support American children's achievement in science. This report also explored the status of science education in the early childhood years. Concern about the quality of science teaching was also evident in a report by the National Commission on Mathematics and Science Teaching for the 21st Century (2000). This report directed national attention toward the urgent need to improve students' performance in science. The main message in the report was that students' performance in science and mathematics was unacceptable. One reason for this was that children in the United States were falling behind when compared to children from other nations. The report also claimed that early childhood teachers were ill prepared to incorporate appropriate science experiences into children's education, and consequently, science teaching is typically absent in early childhood programs.

According to the National Research Council (1996), regardless of age, gender, cultural or ethnic background and interests, with appropriate learning opportunities, all children can develop the knowledge and skills to achieve different degrees of science understanding. This cannot be achieved without access to professional and well trained teachers, adequate classroom time for teaching science, and appropriate science materials and resources (National Research Council, 1996). Furthermore, it is claimed that very little science is taught in the early grades, and that this lack of science teaching could contribute to underachievement in science. Science tends to be a neglected topic in early childhood classrooms because it is "perceived and presented as too formal, too abstract, and too theoretical – in short, too hard for very young children and their teachers" (Johnson, 1999, p.19).

Using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-1999 (ECLS-K) the current study sought to determine how often science was taught in kindergarten classes. Additionally, the data was examined to determine the types of science topics that were addressed and taught in kindergarten, as well as the instructional strategies and resources that teachers used in teaching science in their kindergarten classes. The study also sought to determine the effect of science teaching in kindergarten on children's achievement in science. To this end, children's scores on measures of science learning were examined to estimate their progress in science learning, as well as the relationship between classroom instruction and student learning in science. In doing so, the analyses took into consideration the influence of gender, socioeconomic status (SES), and race/ethnicity on children's academic performance in science.

The participants were kindergarten students who had completed the general knowledge assessment instruments in fall 1998 and in spring 1999 of their kindergarten year, and spring 2000 when they were in first-grade. For this study, only first-time kindergarten students were included, and students identified as learning disabled were excluded. The data was restricted to the sample by including only students who remained in the same school across the base year and into first-grade.

The first two research questions (how often science is taught in Kindergarten? and what topics are taught in Kindergarten?) were analyzed using descriptive analysis. The descriptive analyses included frequencies, means, minimum and maximum values, and standard deviations for the variables, such as gender, race/ethnicity, socioeconomic level, and science topics. Additionally, Pearson Product Correlation Moment correlations and mean comparisons, along with effect sizes were provided. Hierarchical Linear Modeling (HLM) analytical techniques were employed to examine children's progress in science. These analyses focused on several key aspects of science teaching and learning in kindergarten including the frequency of science lessons, the time devoted to teach science, the types of science topics that are addressed in kindergarten, as well as children's scores on measures of science achievement. Hierarchical Linear Modeling (HLM, 6.06 version) was used to analyze research questions 3 through 6. First, the analyses provided an estimation of an unconditional model before adding the student- and school-level predictors. All variables that did not have a meaningful zero were grand mean centered.

Research questions 3 and 4 were investigated by using cross-sectional data analyses by way of two-level HLM modeling.

The research questions addressed by using HLM statistical procedures are as follows:

Question 3. Are there differences in students' science scores, as measured by the direct (IRT) and indirect (ARS) assessment batteries in kindergarten and first-grade, by children's exposure to science activities and skills?

Question 4. Does the relationship between the frequencies and types of science practices and children's science knowledge, as measured by the direct (IRT) and indirect (ARS) assessment batteries differ by children's gender, ethnicity, and socioeconomic status?

In addition to the cross-sectional multilevel analysis, a similar approach was used to address research questions 5 and 6. Here the kindergarten data was analyzed by using three-level HLM growth modeling.

Question 5. What is the longitudinal effect of science teaching and learning on kindergarten students' science achievement as measured by the direct (IRT) and indirect (ARS) assessment batteries?

Question 6. Does the growth of children's science knowledge during the kindergarten year vary by children's gender, ethnicity, and SES?

The following section presents the key findings of the study. First, four cross-sectional two-level analyses results are displayed. This is followed by results of the longitudinal three-level analyses. The findings of these analyses are analyzed in regard to the child level demographics of SES, gender, and race/ethnicity. Then, the relationship between children's science achievement and school level variables, based on both IRT and ARS scale scores, is discussed.

Key Findings

The key findings of the study are summarized below:

- Science teaching and learning in kindergarten level is limited.
- Teachers tend to use previously planned activities as opposed to letting children lead or select their own activities according to their own interests.
- Teachers tend to emphasize topics in the biological sciences, and in health, at the expense of physical science topics.
- The most commonly taught science topic in kindergarten was 'weather' and the least commonly taught topic was 'machines/motors'.
- Physical science topics seemed to be avoided.
- A high percentage of the teachers believed that physical science topics should be taught at higher grades.
- There is no clear consensus about what kindergarten teachers teach in their science classrooms because of between school variations.

- There is a strong relationship between socioeconomic status (SES) and science achievement in kindergarten and first-grade. The impact of SES on science tended to decrease from kindergarten to first-grade.
- After controlling for student and school level variables, the results revealed that IRT scale score results were completely in contrast with the ARS scale scores. The IRT score results indicated that male students consistently outperformed their female classmates. The ARS scale scores indicated that female students performed better than male students.
- There was no relationship between students' gender and effect of school level science practices on their science achievement.
- Children's performance in science varies by their ethnicity.
- Overall Caucasian children's science scores both in kindergarten and first-grade and learning rates in kindergarten were higher than the scores obtained by children from other ethnic groups.
- African-American children's learning growth rate was significantly lower than that of mainstream children.
- When minority and nonminority students are in the same class or school, and have equal access to science instructions and activities, minority children's achievement is still inferior.
- School level science practices influenced children's scores differently based on their ethnicity.

The findings listed above are explained and discussed in the following section.

Discussion

Science Instruction in Kindergarten Level

The current study found that science teaching and learning in kindergarten level is somewhat limited. Only 18% of the Kindergarten teachers reported that they taught science on a daily basis. Furthermore, the majority of those who taught science on a daily basis reported spending little time teaching science. Explaining and understanding why teachers spend such little time teaching science is beyond the scope of the data used in the current study. There are several plausible reasons for the lack of science teaching in kindergarten.

One reason could be that science teaching takes more preparation time and effort in comparison to other subject areas. Some researchers believe that if there is limited time for teaching all subjects in the kindergarten classroom, or if teachers feel that teaching science is not worthwhile, then they tend to postpone or avoid teaching science (Appleton & Kindt, 1999).

The current study's findings are consistent with research findings that were reported almost two decades ago (Stefanich & Kelsey, 1989). Similar findings have also been reported by Dickinson, Burns, Hagen, & Locker (1997) and Johnson (1999). It seems, therefore, that not much progress, in terms of early childhood science teaching, has been made in the last twenty years. The data suggests that, typically, science is not taught on a regular basis in kindergarten. This is surprising given that professional organizations, and others, have consistently emphasized the importance of teaching science in the early grades. The consensus of opinion, according to most professional organizations, is that the teaching of science in kindergarten and first-grade is important because the knowledge and experiences learned in the early grades can serve as a foundation for future learning (Lind, 1999; Katz, 1997).

The study's results suggest that during the limited-time that teachers spend teaching science in kindergarten, the instructional approach tends to rely on previously planned or organized activities, as opposed to letting children select their own activities and scientific investigations. That is, there is some evidence that science teaching in kindergarten is teacher centered as opposed child centered. Even those teachers whose science teaching primarily involved activities that were child-selected, spent a minimal amount of time on such activities.

Science teaching standards have been developed and disseminated by national professional organizations for over a decade. These standards (National Science Education Standards, 1996) emphasized the importance of science teaching and learning in the early grades and they described the content that should be taught. According to this study's findings the science content taught in kindergarten is narrow and somewhat limited. Teachers generally emphasized topics in the biological sciences and in health. The most commonly taught science topics at the kindergarten level were 'weather', health/safe/nutrition/hygiene’ and ‘reading simple graphs’. In contrast physical science topics seemed to be avoided. The data provided one reason why such topics were not taught in kindergarten. A high percentage of the teachers believed that physical science topics should be taught in higher grades. That is, teachers seem to have their own ideas of which topics should be taught in kindergarten and which topics should be taught in other grades, even though these ideas often differ from national guidelines. It is possible, however, that this is a reflection of teachers understanding of how children and their understanding of which science topics are “developmentally appropriate”. After all, for many kindergarten students, their cognitive level is still at the level described by Piaget as the preoperational stage. According to Piaget, this cognitive development stage begins around 18 to 24 months and ends about 7 years of age. During this time, children’s thought processes are much less sophisticated than the thought processes of older children. Also, at this stage, children’s understanding of objects or events, as well as their ability to solve problems, is limited. It is important to take children’s cognitive development level into account when we are interpreting the scope and nature of science teaching in the early grades. Possibly, it is acceptable for teachers not to teach some science topics because understanding some concepts (e.g., light, electricity, solar system and space) require abstract thinking which can be very difficult for kindergarten students. On the other hand, by postponing science teaching until higher elementary- of middle school grades we may be missing an opportunity to introduce these topics to young children. It is important for young children to learn about all areas of science, and that they are presented with an age appropriate as well as a balanced science curriculum.

Ultimately, the success or failure of science teaching in the early childhood classroom depends on the teacher. The professional literature clearly highlights the lack of preparation and self-confidence of teachers in teaching science. This aspect has been identified as and important factor that can work against improving the teaching of science in the primary grades (Abell & Roth, 1992; Appleton & Kindt, 1999; Appleton, 2003; Carol; Fort, 1993; Harlen, 1997; National Research Council, 1996; Osborne, Simon, & Collins, 2003; Seefeldt & Galper, 2007). Ultimately, teachers’ confidence and interest in science teaching determine how often they teach science and how they teach it. On the other hand, teachers' interest in science teaching is also affected by system priorities, and it is not just a personal view or a personal choice. Scheduling problems (official time allocation to science), and other curriculum priorities, might have a negative impact upon teaching, which could result in subjects like science being dropped from the curriculum. All these reasons lead us to believe that in schools there is no systematic support for teachers to teach science, except the teacher's own extra efforts to include science in their daily routine (Appleton & Kindt, 1999). As noted above, however, why kindergarten teachers do not teach science very often, and why they focus on some science topics more than others, is beyond the scope of this study.

Effects of Demographic and School Level Variables on Kindergarten and First - Grade Students' Science Achievement

Socioeconomic Status. Four cross-sectional analyses were conducted to analyze the relationship between student demographic variables (SES, gender, and race/ethnicity) and children's science achievement scores in kindergarten and first-grade. The results of the analyses clearly showed that socioeconomic status (SES) had the most influence on both kindergarten and first-grade children's science achievement. This was true for the IRT and ARS scale scores. The longitudinal analyses of the kindergarten data also revealed that SES continues to influence children's science achievement as children are promoted to the next grade-level. The correlation between SES and children's science achievement was higher for the IRT scale scores than for the ARS scale scores. The findings of this study suggest that there is a strong relationship between SES and science achievement in kindergarten and first-grade. This finding is consistent with the research literature suggesting that SES is related to children's academic performance in school (Bickel, Zigmond, & Strayhorn, 1991; Von Secker, 2004). This also seemed to be the case for children's science achievement in the current study. The trends evident in the data suggest that the science achievement of students from low-SES families declines and falls further behind as they progress through school (Von Secker, 2004). This study's results also suggested that the influence of SES on children's achievement is stronger or "larger" in kindergarten as opposed to first-grade.

The National Research Council (1996) has stated that regardless of age, gender, socioeconomic status, cultural or ethnic background and interests, with appropriate learning opportunities, all children can develop the knowledge and skills to achieve different degrees of science understanding. The results of this study highlight the effect, and possible importance, of other variables such as teacher effectiveness and classroom and/or school level variables, on children's science learning. Understanding the factors that influence science teaching and learning could provide information that might lead to policies and practices that could reduce the achievement gap among children from different SES levels. Indeed, it is believed that reducing the achievement gap is possible when appropriate instructional opportunities are provided (Von Secker, 2004). According to the current study's kindergarten ARS (indirect measure) scores, children with average SES level benefit more from child-selected activities. The longitudinal analyses further showed that a student whose SES was one standard deviation higher than the mean had higher scores, and these students' scores increased as a function of more child-selected activities and with longer or more time spent teaching science in the classroom.

Gender. Another influential student level variable, according to the data, was gender. After controlling for student level (SES and race/ethnicity) and school level (science teaching practices) variables, the IRT (direct assessment) results were the opposite of those for the ARS scores (indirect assessment). According to the IRT scale score results male students consistently outperformed their female classmates. The ARS scale scores were based on teachers' ratings of their own students based on their current and past observations. The analyses for the ARS scores, however, indicated that female students outperformed male students. Since, the ARS assessment battery is based on children's progress as well as the product, arguably it can provide a better understanding of children's past and current skills. That is, the ARS could more accurately represent knowledge and behavior and reflect broader sampling of the most recent national curriculum standards and guidelines from teachers and professionals. It is claimed that, despite the fact that the IRT and ARS assessment items overlap, and that they assess the same curricular domains, the IRT assessment battery is less able to measure the process of students' thinking (US Department of Education, 2001; 2002).

The effect for gender was stronger for the kindergarten IRT scores than it was for the kindergarten ARS scores. This was the case for both the cross-sectional and the longitudinal analyses. Interestingly, the effect for gender became stronger in first-grade. This finding has been apparent in other research studies. The research literature includes similar inconsistent reports for male and female comparisons of science achievement across different grade levels. While some studies (Adamson, Foster, Roark, & Reed, 1998; Greenfield, 1996; Kahle, 2004) show that science achievement mostly favors male students, other studies (e.g., Kahle, Meece, & Scantlebury, 2000) found that gender differences between boys and girls were complex, and they did follow a consistent pattern.

According to the literature, more effective classroom/school experiences can compensate for gender bias in teaching (Blake, 1993; Ebenezer & Connor, 1998; Geiger & Litwiller, 2005; Johnson, 1996). Interestingly, this study did not find any relationship between students' gender and the effect of school level science practices on students' achievement in science.

Race/Ethnicity. The results of the relationship between children's race/ethnicity and their science achievement in kindergarten and first-grade, in general, was consistent with the effects that have been reported in the literature for other areas of the school curriculum such as literacy (Fryer & Levitt, 2004; National Science Foundation, 2005; Osborne, Simon, & Collins, 2003; Tenenbaum, Rappolt-Schlichtmann, & Zanger, 2004; Yager & Yager, 1985). The current study's results revealed that children's performance in science varied by their ethnicity. Overall, Caucasian children's science scores, both in kindergarten and first-grade, were higher than the science scores of children from other ethnic groups. The science achievement gap between Caucasian and other ethnic groups seemed to decrease from fall to spring in kindergarten. This effect was weak, however. Thus, the learning rate for Caucasian students was higher when compared to other ethnic groups. African-American children's learning growth rate was significantly lower than that of mainstream children. This achievement gap between Caucasian children and children from other ethnic groups was particularly evident in the first-grade. The gap between Caucasian and African-American children seemed to widen from kindergarten to first-grade. Similar results were also found for Hispanic children, after controlling student (gender and SES), and school (science practices) level variables.

When analyzing the ARS measure of science achievement, the results were slightly different. Similar ethnicity effects, for example, were evident in kindergarten but not in first-grade. Several plausible reasons could explain the nonsignificant effect of ethnicity on children's ARS science achievement. First of all, the ARS reflects teachers' observations of their own students, and therefore they are arguably closer to the reality of students' science achievement. This being the case, then it is possible that the ethnicity effect is minimal. Yet, the study does not provide any data for such an explanation. Arguably, nonsignificant effects of children's ethnicity on their science achievement may also show their progress in science and/or positive effects of different student and school level variables. Additionally, standardized IRT and nonstandardized ARS scale scores were based on different scales. On the other hand, it is equally possible that the measure of science achievement was not sensitive enough to detect differences in science achievement across based on students' race. Since, a precise explanation is beyond the scope of this study, further research is recommended.

The interaction between children's ethnicity and school science practices was also investigated. To this end, the study examined children's science achievement (ARS and IRT). Previous studies have demonstrated positive as well as negative effects of minority status on children's science learning (Von Secker & Lissitz, 1999; Von Secker, 2002, 2004). For the IRT scale scores, the cross-sectional and longitudinal analyses of kindergarten data revealed that children from 'Others' group, which included Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and non-Hispanic multiracial children, did not benefit from child-selected classroom activities. Children from the same ethnic group, however, seemed to have higher science IRT scores when they had frequent opportunities to engage in science activities. In the first-grade, African-American, Hispanic, and Asian students' IRT scores increased as a function of different science activities (child-selected activities, frequent science activities, and science equipment use). Teachers' ratings (ARS) of those children from different ethnic groups also revealed that while some children were benefiting from school science practices, for others those practices had a negative impact on their science scores. African-American children's scores, for instance, decreased as a function of more frequent use of science equipment. On the other hand, the longitudinal analyses of the ARS scale scores in kindergarten indicated that African-American and Hispanic children had higher scores when they had longer periods of time for science. This study's results, along with findings from previous studies (Von Secker & Lissitz, 1999; Von Secker, 2002, 2004), suggest that when minority and nonminority students are in the same class, and when they have equal access to science instruction and activities, the science achievement of minority children's achievement is still inferior, particularly in the lower grades. Academic achievement of minority students might be particularly sensitive to the opportunities structured by school policies. These issues are beyond the scope of this study, and therefore further research is recommended.

Implications for Policy and Practice

This study's findings suggest a need to take a fresh look at the content of early childhood science, and the efficacy of science instruction with young children. The research results suggest that quality science instruction plays an important role in early learning. Moreover, it seems that daily science instruction can have a discernible influence on children's science learning (Novak & Musonda, 1991). It is important, therefore, to create a classroom environment that is conducive to science learning and one that every child can get benefit from. According to this study, efforts to support the national goal of improving science literacy for all Americans should begin at the kindergarten level. Therefore, policymakers and researchers should revisit science teaching in early grades.

This study's results also shed light on how science teaching and learning practices in early childhood settings can effect young children's achievement in science. The findings of this study have identified several student and school level factors that can influence young children's science achievement in kindergarten and first-grade. Although there were inconsistent conclusions about male and female students' science achievement, as assessed by the direct and indirect assessment batteries, contrary to expectations, there was no association between children's science scores and their gender and the amount or degree of science practices they received in their classrooms. These results appear to highlight the difference between direct and indirect assessment measures and their reliability in assessing children's achievement.

Standardized and nonstandardized tests have received negative as well as positive feedback from researchers. Indirect assessment of children's performance, however, has received more attention, possibly because of the belief that it is influenced by teacher expectation, and thus is subject to teacher bias. It has also been claimed that since teachers observe and interact with students on a daily basis, they are in the best position to evaluate children's accomplishments across different areas of the curriculum (e.g., intellectual, socio-emotional, and behavioral) (Calfee & Hiebert, 1991; Kenny & Chekaluk, 1993; Perry & Meisels, 1996). Concerns about the trustworthiness (i.e., validity and reliability) of teachers' ratings of their students have also been expressed in the literature (Hoge & Coladarci, 1989; Perry & Meisels, 1996). Publications by the National Center Educational Statistics clearly reported reliability statistics for the standardized General Knowledge Scores for fall and spring of kindergarten, and spring first-grade, .88, .89, and .89, respectively. There is a need, however, in large scale studies such as ECLS-K to evaluate teachers' independent understanding of, and their ability to make judgments (reliability) about students' academic achievement. On the other hand, criterion-related and the predictive validity of teachers' judgments seem to provide satisfactory results. It should also be noted that attention needs to be paid to the domain in which teachers are being asked to make judgments, because it has been reported that the characteristics of children such as, age, gender, ability/achievement level, and linguistic and cultural diversity can influence their judgments (Perry & Meisels, 1996). The effects of student demographics, however, require more thorough in-depth investigation across all grade levels, and especially in the early childhood and elementary grades. This is because teachers' lack of knowledge in these areas can lead to inaccurate judgments. Clearly, such observations are beyond the scope of the current study and therefore further research should examine teachers' judgment of student performance and the effects of student level characteristics on academic achievement.

Both direct and indirect assessment results revealed that science teaching practices have different effects on children from different SES level and race/ethnicity group.

Oftentimes children and their family socioeconomic status and ethnicity are seen as the root cause of underachievement in different subject areas. In the seminal studies conducted by Coleman et al. (1966) and Jencks et al. (1972) it was noted that "the majority of the differences in student achievement can be attributed to factors like student's natural ability or aptitude, socioeconomic status of the student, or the student's home environment' (p.2) and it was also found that the differences in achievement were "due to factors the school cannot control" (p.2) (as cited in Marzano, Pickering, & Pollock, 2001). With appropriate instruction, however, it is possible that the school can make a difference in children's academic achievement. In particular, the classroom teacher has even more of an effect on student achievement than what was originally thought. Research conducted since Coleman and Jencks studies has shown that with age appropriate learning opportunities in well developed classroom environments, as well as appropriate and effective teaching practices, teachers can have a significant effect on children's academic achievement. According to Ding and Navarro (2004), however, the gap between different ethnic groups cannot be closed in the short term. Therefore, there is a need for teacher preparation that promotes sensitivity to the needs of minority children in the long run (Lee, 1997; Marzano, Pickering, & Pollock, 2001; National Research Council, 1996).

Perhaps one of the most important contributions of this study is the finding related to inconsistent effects of different science practices on children's science achievement. The results showed that science instruction effects some children's science achievement more than others. The results can lead to important implications both for the policies governing early childhood science teaching and curricula, and for science teaching practices in the early grades. A clear demand exist for extension of resource materials to include other topics, more child-selected activities, integration with other subject areas, and more quality time for science teaching and learning activities.

Recommendations for Future Research

The longitudinal nature of the ECLS-K data provides generalizable results to the United States population of kindergarten children, teachers, and schools offering kindergarten program in the 1998-99 school year. The findings of this investigation have led to conclusions which could be used to guide future researchers. First of all, teacher level variables can be added to determine different reasons why teachers in the early grades do not teach science more often. Another topic for research is the relationship between teachers' self-confidence in teaching science, participating professional development activities, education level, and years of teaching experience. Some other school factors, and even district level variables, were not investigated in this study (e.g., quality of school resources, school SES status). Since, the current study only included children who were attending public schools future studies should include children from private schools, and even home-schooled children. School level variables and system factors may interact with teacher level variables in ways that were not evident in the current study.

Another potential direction for future research would be to examine influences of variables that provide more information about children's characteristics such as, family characteristics, home environment, school enrolment age, and school readiness. Additionally, since young children's science ability is highly related to their language development, future research could test this relationship.

Conclusion

This study attempted to understand the connection between science teaching practices in schools and kindergarten and first-grade students' science achievement. In addition, the study examined some of the factors that potentially influence children's learning in science. Statistical modeling techniques were used to examine the relative importance of selected variables, including gender, race/ethnicity, socioeconomic status, and various aspects of science teaching in the area of science based on direct and indirect assessment battery scores. This study found that science teaching and learning in kindergarten is limited. Moreover, inconsistent results were found about the effects of science teaching and learning practices on kindergarten and first-grade students' achievement in the area of science knowledge, based on student characteristics. Given the findings of this study, educators and policy makers should pay attention to the way teachers deliver science instruction in the early grades.

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BIOGRAPHICAL SKETCH

Refika Olgan earned a Bachelor’s degree in Child Health and Development at Hacettepe University, Ankara, Turkey. She worked for a Turkish public school system for four years as a kindergarten teacher and as a school supervisor. The Turkish Ministry of Education awarded Ms. Olgan a prestigious scholarship, and sponsored her graduate studies at the Texas A&M University – Commerce, where she received a Master of Science degree in 2003. Refika continued her advanced graduate studies at the Florida State University where she earned a Ph.D. degree in Early Childhood Education in 2008.

During her Ph.D. candidacy at the Florida State University, Refika was Assistant Director of the College of Education’s Office of Information and Instructional Technologies. She also taught an undergraduate course, *Parents as Teachers*. She was actively involved in research, and presented several research papers at national and international conferences.

During her graduate studies in Texas and Florida, Refika was awarded certificates for academic excellence from the Turkish Ministry of Education. She was also awarded the *Julia Schwartz Endowed Scholarship* and the *Donna Lou Askew Scholarship* by the Florida State University, College of Education.

Ms. Olgan’s research interests include teaching and learning science in the early grades, young children’s understanding of mathematics, parental involvement in early childhood education, and educational applications of technology in the primary grades.