# FREQUENCY, DURATION, AND TIME DEVOTED TO ELEMENTARY SCIENCE INSTRUCTION AND THE ASSOCIATION WITH SCIENCE ACHIEVEMENT AND SCIENCE INTEREST

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APPROVAL OF THE DISSERTATION

This dissertation, "Frequency, Duration, and Time Devoted to Elementary Science Instruction and the Association with Science Achievement and Science Interest", has been approved by the Graduate Faculty of the Curry School of Education in Partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

Although the United States continues to lead in many STEM areas (i.e., research and design and productivity), the Science and Engineering Indicators (NSB, 2010) suggest that the country is experiencing an erosion of its STEM advantage, ultimately losing the edge in each of these areas. Looking at trends in K-12 science, the 2010 National Science Board report indicated that the United States' position among selected countries declined in fourth grade science (NSB, 2010). This trend raises concern about the lagging student interest in the natural sciences, and thus the fate of science achievement outcomes for students in the United States. The research questions addressed in this study were:

> What is the pattern of growth for first-time kindergartners in science achievement from the end of third grade to the end of eighth grade?
>
> Controlling for differences in student demographics, are gains that first-time kindergartners make in science achievement from the end of third grade to the end of eighth grade associated with the frequency, duration, and time devoted to science in the third grade?
>
> Controlling for differences in student demographics is the frequency, duration, and time devoted to science in the third grade associated with the students' interest in eighth grade science?

A subset of the variables contained in the ECLS-K: Early Childhood Longitudinal Study, Kindergarten Class of 1998-1999 data set and a subsample of the cohort of students in the ECLS-K data set.

An unconditional growth model indicated that science achievement followed a non-linear pattern with significant individual variation in trajectories. In addition, students beginning with lower initial science achievement experience more rapid growth than those students beginning with higher initial science achievement. A conditional growth model suggested that the frequency of science in the third grade was a significant predictor of the achievement trajectory in science above and beyond demographic variables. The duration of science in the

third grade was not a significant predictor of the achievement trajectory in science. The results of a linear regression analysis suggested that the frequency and duration of third grade science was not associated with science interest in the eighth grade.

This work is dedicated to my many teachers, whose classrooms I was a member of from kindergarten to the twelfth grade and the educators I have had the pleasure of working with throughout the country.

In particular, Sally Cross, my sixth grade science teacher, who is responsible for my decision to be a teacher. Every child should have a "Ms. Cross."

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# CHAPTER 1

# INTRODUCTION

## Why Elementary Science Education?

Science education has been thrust to the forefront of almost all aspects of educational, political, and economic debates. The continual advancements of the sciences and technology in society require increasing the demand for productive scientists and engineers in the workforce while at the same time producing a more informed public. To respond to this continual advancement, the United States has undergone several reformations in science education along with the education of students in technology, engineering, and mathematics. Historically, science education reform has been in response to world events (i.e., the Cold War and Sputnik) that create a sense of urgency in the education our children (Rudolph, 2002) as well as the release of policy directed at the shortfall in the achievement outcomes of America's science students (i.e., The National Science and Engineering Indicators, *Rise Above the Gathering Storm,* and *Taking Science to School* documents). Beyond the education of children, these reform efforts often address economic concerns and implications associated with the failure to maintain an educated public and productive workforce development in the sciences, emphasizing the importance of a quality science education on the future of the country. For example, The National Science and Engineering Indicators (NSB, 2010) are comprised of thirty-one indicators that detail the status of United States science and engineering relative to the rest of the world. These indicators highlight broad trends in areas such as workforce development, research and design, and productivity in science as well as technology, engineering, and mathematics.

Although the United States continues to lead in many areas (i.e., research and design and productivity in the sciences), the Indicators suggest that the country is experiencing a gradual erosion of that advantage and ultimately losing the edge in these areas. More specifically, the European Union and Japan have recently experienced a rapid growth in the number of individuals who pursue advanced education in science, technology, engineering, or mathematics. Looking at trends in K-12 science, the 2010 National Science Board report also indicated that the United States' position among selected countries declined in fourth grade science (NSB, 2010). Additionally, the gap between more and less advantaged students remained the same over a span of five years (NSB, 2010). This trend not only highlights a significant and persistent challenge in science education, it raises concern about the lagging student interest in the natural sciences, and thus the fate of science achievement outcomes for students in the United States. In light of the multiple reform efforts dating back to the 1960's, the positive sustained change in science achievement appears absent, and, in many cases, the initial disparities in science skills and understanding have become larger (NSB, 2010). The potential impact of this failure to close the gap may have a significant and negative impact on the economy in the United States (Marx & Harris, 2006; NAS, 2005).

Given the issues presented in science education and the multitude of stakeholders in the educational outcomes of the sciences, developing a solution or intervention to address these challenges is in the best interest of both our young students and the nation as a whole. One such area of research within science education that may be fruitful in this pursuit looks at student interest in science and the stability of this interest over time. Capturing and maintaining student interest is an essential part of the learning process, thus capturing and maintaining student interest in science may lead to persistence in science education, pursuit of science-related careers, and to successful outcomes for the United States. Seminal work in this area by Tai, Liu, Maltese, and Fan (2006) found that the career aspirations of eighth graders, above and beyond academic achievement, predicted the likelihood of earning undergraduate degrees in the science-related fields (e.g., biology, physics, chemistry, and engineering). Subsequently, a longitudinal study by Lindahl (2007) indicated that students indentify interest as the most important factor in persistence in science through school. Additional research has looked at experiences reported by current scientists and graduate students in science disciplines (Maltese & Tai, 2010). Over 65% of the participants indicated that their interests in science began before their middle school years (Maltese & Tai, 2010). The consistent message in the research on interest in science is that the earlier the interest the more likely the student will continue on in the sciences through college major or concentration and career choice. With this in mind, a continued focus on science education reform in the high school seems slightly misguided if the starting point for science interest and the persistence of that interest has been documented much earlier (i.e., prior to the middle school years). Consequently, the attention of science education research may be better focused on what happens in the elementary school.

Surprisingly, calls for renewed focus on elementary science education is not new nor have the essential questions surrounding this focus changed. Bingham (1962) clearly articulates that if the United States educational system is to produce scientifically literate citizens as well as successful and productive scientists, this venture must start in the elementary school classroom. Capitalizing on the natural curiosity and interest of children, the elementary school classroom is the best place not only to teach children about science, but also to introduce them to the process of doing science (Bingham, 1962). Researchers have continued to echo this call for the introduction of science as early as possible (Rillero, 2005; French, 2004; Gould, Weeks, & Evans, 2003; Kokoski & Downing-Leffler, 1995). Beyond a call for the earlier introduction of science, the body of research surrounding elementary science education has not provided clarification on the fidelity, nature, or outcomes of these earlier experiences. Put another way, simply calling for early science experiences will not be effective if these experiences are not provided to America's science students and the outcomes measured.

## Science Education Policy and Elementary Science

Similar to the call for the early introduction of science, educational organizations and policy groups within the United States have also responded to the opportunities and challenges associated with elementary science education. Ranging from policy documents to position statements, each organization emphasizes similar themes including the interaction of scientific content and processes, classroom environments, and the importance of ethnic and cultural diversity in science learning. For example, in 2002 National Science Teachers Association (NSTA) released an official position statement regarding elementary school science emphasizing the necessity for the development of understandings and skills through first-hand experiences that build on prior knowledge and are organized under big ideas or themes. In addition, the NSTA firmly believes that the fostering of positive attitudes about science and the integration of science with other disciplines are vital to preparing and motivating students to participate in the global community.

Approximately five years later, the National Research Council released *Taking Science to School. Learning and Teaching Science in Grades K-8* that addressed three core questions surrounding science education in grades K-8: How is science learned, how should science be taught in the K-8 classroom, and what are the research gaps in the understanding of K-8 science education? This particular policy documented summarized key findings as well as proposed recommendations about the future direction of work in this area. What is most relevant to this discussion is the statement regarding the development of scientific knowledge in children and the importance of early experiences in this development:

> Rather, cognitive capacities directly related to scientific practice usually do not fully develop in and of themselves apart from instruction, even in older children or adults. These capacities need to be nurtured, sustained, and elaborated in supportive learning environments that provide effective scaffolding and targeted as important through assessment practices (Duschl et al., 2007, p.45).

This statement alone points to a focus on the type of environment, instruction, and individual factors (e.g., ability levels, interest, and demographic characteristics) that may play a role in the development of necessary cognitive capacities for scientific practice and thus scientific achievement. Even more relevant to this discussion and an implied message in the above excerpt is that Duschl et al. (2007) strongly recommend that students have early access to this instruction. To put it succinctly, students need to have science class.

In 2007, the National Science Board prepared and presented a national action plan focusing on science, technology, engineering, and mathematics education (STEM). Taking into account all of the stakeholders in the improvements and success in STEM education, this action plan presents what the Board believes to be priority actions necessary for the improvement and continued success in United States STEM education. With regard to science, this action plan suggests that the United States should take steps to ensure coherent science learning, provide national science guidelines with essential knowledge and skills for each grade level, and promote the alignment of this curriculum throughout the public education system (NSB, 2007). This alignment relies on the development of essential knowledge and skills from early science instruction.

In combination with the Indicators on the status of science and engineering in the United States, the policy documents discussed previously may prove to be fruitful in improving science education, and thus maintaining the advantage the United States has enjoyed in these fields. However, there is a paucity of research that takes into account the combined message of the policy documents (i.e., *Taking Science to School* and *The National Action Plan)* and previous work on early interest and early experiences in science (i.e., Tai et al., 2006; Rillero, 2005; French, 2004; Gould, Weeks, & Evans, 2003; Kokoski & Downing-Leffler, 1995). In other words, little work exists on the pattern of science achievement in the elementary school, the importance and nature of elementary school science experiences, and the role these experiences play in subsequent science achievement. Furthermore, the underlying assumption among the previously discussed documents is that students have access and exposure to science in the elementary school. This assumption may not be valid. Pianta et al. (2007) found that only 11% of the time in a fifth grade classroom was allotted for science activities. Given that 17% of the time in fifth grade was set-aside for instructing students on managing materials and time, 11% for science is both appalling and alarming. The investigation of frequency, duration, and time devoted to early science experiences is an essential starting point in responding to both the Indicators and National Action Plan presented by the National Science Board as well as other documents focusing on the improvement and success of science education. How much time is being spent on elementary science instruction and how is this associated with science achievement?

## Purpose of this Study

The purpose of this study is twofold. First, this study seeks to describe the nature of science achievement prior to high school (i.e., grades three through eight). This will provide a general picture and baseline for the pattern of science achievement early on in science education. Additionally, this study will investigate the amount of time devoted to science in the elementary school classroom. More specifically, this study will look at the association between the frequency, duration, and time devoted to science in elementary school and science achievement. The research questions that will be addressed by this study are:

1. What is the pattern of growth for first-time kindergartners in science achievement from the end of third grade to the end of eighth grade?
2. Controlling for differences in student demographics, are gains that first-time kindergartners make in science achievement from the end of third grade to the end of eighth grade associated with the frequency, duration, and time devoted to science in the third grade?
3. Controlling for differences in student demographics is the frequency, duration, and time devoted to science in the third grade associated with student interest in eighth grade science?

The research questions will be addressed through descriptive statistics as well as growth curve modeling and linear modeling. Each of the analytic models will be developed to control for student demographic characteristics.

## Significance of this Study

The significance of this study lies in the longitudinal investigation of science achievement. It will contribute to the overall picture of the progression of science achievement in the early stages of science education and allow for the study of how earlier events and decisions are associated with achievement and interest in subsequent years. This study incorporates both the research on early interest development in science, the importance of early experiences in science, and the nature of science achievement within the United States. The focus on the amount of exposure students have to science experiences in the elementary school and student science achievement will provide useful information on the time devoted to science at an age and time that research suggests is extremely important in the development of interest. Furthermore, the emphasis on longer-range outcomes associated with the amount of science in elementary school will potentially help clarify the breadth of these early experiences. This study will provide insight into the nature of science achievement as students move through the third to fifth grade, transition to middle school, and prepare for entrance into high school. Developing a better understanding about what contributes to science achievement provides a greater chance of making research-driven decisions and the implementation of effective policies in the United States science education system.

# CHAPTER 2

# REVIEW OF LITERATURE

> Science begins for children when they discover that they can learn about the world through their own actions, such as blowing soap bubbles, adding a block that causes the structure to collapse, or refracting light through a prism. A child best learns to swim by getting in the water; likewise a child best learns science by doing science (Rillero, 2005, p. 8).

The three research questions presented in the previous chapter are based on four assumptions about elementary science education, the frequency, duration, and time devoted to elementary science instruction, and the association of those time amounts on subsequent achievement and engagement. The assumptions underlying these research questions are: first, that early exposure to formal science experiences is an important component in the science education of students; second, it is not just the nature of these early science experiences that is important, but that an allotment of time is devoted to these experiences in the elementary school classroom and cannot be postponed until later years of formal instruction; third, science achievement and interest development are the result of several factors over multiple years of formal science education and not the result of one single factor or year; finally, there is a specific knowledge base and skill set that is nurtured only through formal, elementary classroom science experiences and cannot be developed alone from informal settings outside of the classroom. It is the combination of these assumptions that leads to the manifestation of behaviors expressing a student’s interest in science. What follows is a review of the literature that provides support for each of these assumptions.

The collection of empirical evidence associated with various and often overlapping areas of research provide the justification for the assumptions as well as the relevance of the research questions. This review of literature focuses on the following topics: early experiences in science, early interest in science, the association between interest and achievement, demographic factors and their association with achievement, the frequency, duration, and avoidance of elementary science instruction, and the manifestation of interest in the science classroom. In addition to these topics, this review incorporates several topics that are above and beyond the assumptions and research questions in this study. The rationale for including these additional topics is that these strategies, activities, or components might otherwise not be available to elementary school students outside of the formal setting. Put differently, these topics provide a glimpse at what students would be missing if they were not offered elementary science experiences in their classroom or school. This provides a more developed context in which to interpret and discuss the results of this study. However, the additional issues or questions raised by these additional topics are above and beyond the focus of this study.

## Early Experiences in Science

The body of literature that addresses early experiences in science can be classified into two categories based on the primary focus of the particular review or study: (1) the means of acquiring scientific knowledge and (2) the development of early ideas about natural phenomena (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Fleer & Robbins, 2003a; 2003b). A comprehensive review of how students acquire scientific knowledge or a focus on students' early ideas about specific phenomena would distract from the purpose of the current review. However, two key lessons learned are well documented in previous research and contribute to the current review. First, children develop ideas about physical phenomena at an early age (Driver et al., 1994). Secondly, these ideas, regardless of their accuracy, are developed through everyday experiences (e.g., Fleer & Robbins, 2003b; Stein & McRobbie, 1997; French, 2004; Gelman & Brenneman, 2004; Tytler & Peterson; 2003). What follows is a review of literature on the role of early experiences on the development of scientific ideas (i.e., Stein & McRobbie, 1997; Rahayu & Tytler, 1999; Thomas, 1999) as well as the readiness of elementary school students for acquiring scientific knowledge (i.e., French, 2004; Gelman & Brenneman, 2004; Tytler & Peterson, 2003).

The development of scientific ideas through experiences is often referred to as constructivist learning (Driver et al., 1994). This acquisition of scientific knowledge is presumed to take place in various social contexts and not in isolation. As a result of these contexts, students not only develop ideas about science content, but students also develop an understanding about the nature of scientific ideas (Stein and McRobbie, 1997). Stein and McRobbie (1997) investigated 151 students ranging from the fourth grade through the final year of compulsory schooling. These students were asked to free-write about scientific phenomena and how these students interacted with scientific phenomena. Using a phenomenological approach, Stein and McRobbie (1997) found that students' early experiences in science greatly influenced how they viewed the nature of scientific ideas in subsequent years. Furthermore, the development of such beliefs often required the explicit instruction about scientific knowledge. Put differently, how students' view scientific knowledge (i.e., an obtained truth, an accumulation of discrete facts, or as a continual process of exploration) depends predominantly on the nature of students' earliest experiences with science. An understanding of the nature of scientific knowledge ultimately contributes to the development of specific ideas in science (e.g., burning substances or chemical changes). A second outcome of this study refers to this progression of scientific knowledge for individual students. As students gain more experience with science learning, their scientific knowledge continues to develop through a process that is notably different from those students that are not offered experiences in formal science learning.

Children in early primary education (i.e., the first two years of formal schooling) show a steady growth in their scientific reasoning ability when exposed to early experiences in science education (Tytler & Peterson, 2003). Using a qualitative and interpretive approach, fourteen individual children were followed over a period of two years. Following a sequence of activities designed to challenge and explore student conceptions about science, selected students were interviewed about their understanding of the tasks and content topics. The interviewers were particularly interested in understanding the students' scientific reasoning ability about content topics such as mechanics, material changes, and animal adaptations. This research suggests that young children are capable of scientific reasoning by coordinating ideas and evidence. This reasoning process appears to be more descriptive and pattern development rather than the control of variables, a process documented in developmentally older students. Therefore, Tytler and Peterson (2003) assert that more opportunities must be available for young children to engage in ideas and pattern development with scientific content instead of assuming they are not ready cognitively for such tasks. These opportunities are ideal for primary or elementary school classrooms in which teachers scaffold the interaction between student ideas, questions, and reasoning.

As a brief aside, classroom practices and teacher beliefs also contribute to the development of beliefs about scientific knowledge (Brickhouse, 1990; Tobin, 1993; Lakin & Wellington, 1994). Although this body of literature deserves mentioning, these studies are beyond the focus of the present review. What is evident in the Stein and McRobbie (1997) and the Tytler and Peterson studies is that early experiences influence how students conceptualize scientific knowledge, how students develop specific scientific ideas, and that young learners are capable of interacting with these ideas at an early age.

Specific examples of young learners' progression of scientific ideas are well documented in the research literature. Rahayu and Tytler (1999) looked at the progression of children's conceptions about the burning of substances and chemical changes. Again, the specific concept (e.g., burning of substances) is not as pertinent to this review as the overall progression of conceptual understanding. This study investigated the beliefs of six, seven, and eight year olds about the burning of substances. The students in this sample, 21, 26, and 26, respectively, were selected from an Australian primary school and had not had any formal instruction about burning or chemical changes. The participants took part in a series of group activities involving the burning of substances along with a follow up discussion lead by one of the researchers. These discussions were recorded and analyzed. By selecting three subsequent age groups, this study sought to describe the conceptual trajectory of a science idea, in this case, burning. Rahayu and Tytler (1999) hoped to clarify the coherent sequence of this conceptual development. The results of this study point to the idea that students express ideas about science phenomena that are highly contextual or specific to certain situations. The progression of understanding associated with the concept of burning substances appears to be dependent on the students' access to the idea and experiences associated with the idea of burning. These experiences lead to better language development in regard to how the phenomena is explained or described.

Most notably, Rahayu and Tytler (1999) contend that a student's progression about science ideas is an outcome of progressing through the primary school years. This progression offers the student access to a wider range of experiences, access to a wide range of subsidiary experiences, and thus more control over other variables associated with the concept. This research suggests that early experiences are not only important for the development of ideas about science, but are vital to the progression of these ideas to a more complete and refined state.

Ravanis and Bagakis (1998) used a pre-test, post-test design to assess 49 kindergarteners understanding of gasification. The pre-test consisted of semi-directed interviews that were recorded and analyzed for a conceptual understanding of water vapor formation. None of the participants had prior formal science education. The intervention used in the study took place one month after the pre-test and utilized picture cards that displayed the water cycle via an open bottle apparatus. Students were asked to describe the sequence of the cards in a narrative as if telling a story about the water and the formation of water vapor. The results of this study were striking in that the post-test results showed a significant improvement in kindergarteners' understanding of the water cycle, in particular, water vapor or gasification. The outcomes of this study indicate that early experiences in formal science education contribute to the development of conceptual understanding of science content. These results contribute to this review by providing empirical data supporting the influence of early formal science instruction on the development of scientific ideas.

What outcomes can be expected if student beliefs about science are not refined or an environment that promoted the progression of ideas about science was absent? Thomas (1999) investigated the barriers of this conceptual progression by looking at three $11^{th}$ grade chemistry students for a period of 18 weeks. The purpose of this interpretive study was to look at why students were resistant to change their conceptions of learning, avoid improvements in their learning, and investigate the role of the teacher and student in these resistant behaviors. At first, this study seems slightly out of line with other studies presented in this review. However, the results suggest an alternative and somewhat negative outcome to early experiences in science education. Through the use of stimulated recall interviews, video excerpts from classroom sessions, interviews with students about assessment scores, journal entries, self-concept and classroom environment questionnaires, and field notes, Thomas (1999) found that student beliefs about science and behaviors exhibited in the process of learning science were formed and developed from the earliest stages of the students' educational career. The resistance to conceptual change was most often linked to these prior beliefs. Although the study found additional contributors to the resistance, the predominant theme of early experiences is particularly relevant to this review from both a content perspective (i.e., early experiences leading to the formation of early ideas) as well as learning habits (i.e., how students approach the learning of science). In both cases, the resistance of students to change their conceptual beliefs was rooted in early experiences that later seemed to serve as impediments to the later progression of science learning.

To capitalize on the importance of early experiences in science, several early childhood science curricula have been developed to provide early formal science experiences to children. The success of these programs has been measured through several achievement indicators, most often vocabulary development and literacy skills. For example, French (2004) developed and assessed the influence of a four-module science curriculum that lasting approximately 10 to 12 weeks on linguistic levels in preschoolers. The curriculum, referred to as ScienceStart! (French, 2004), is both highly structured and aligned with benchmarks for scientific literacy. The sources of data for this study included teacher impressions, parental impressions, narrative assessments, and standardized measures. The outcomes of the study indicate that structured, formal science instruction results in the improvement of science knowledge as well as an increase in performance in other areas such as literacy and language development. Although not generalizable to the entire preschool population, this study seems to suggest that early formal science instruction positively contributes to the academic success of students. More importantly, this study provides results that also suggest students are ready for formal science experiences at an early age. This is in line with the results of Tytler and Peterson (2003) that suggests children are more prepared and capable of scientific reasoning than is often suggested in other research and curricula.

Gelman and Brenneman (2004) also challenged the notion that young children are often not prepared for advanced scientific reasoning. In collaboration with a team of developmental psychologists, the program Preschool Pathways to Science (Gelman & Brenneman, 2004) was developed to provide math and science experiences to pre-K students. The program was designed around embedding the scientific method within activities, the use of relevant language, creating conceptually connected experiences, and focusing on central ideas. In addition, this program links science to other curricular areas to provide a comprehensive preschool program. The drawback of this program is its lack of research supporting implementation. In other words, to date, no data has been published on the effectiveness of the program. The benefit of mentioning this program in the current review lies in the theoretical framework that accompanies the program. Gelman and Brenneman (2004) suggest that the developmental characteristics of pre-K students are both compatible and conducive to early formal science experiences. Students at this age are ready for formal science learning and could benefit from the experiences. This also is in agreement with the vast body of research on the early development of scientific reasoning. Often referred to as the child as scientist, a multitude of work has looked at the development of scientific reasoning and the natural inclination for scientific reasoning in young children (Sodian, Zaitchik, & Carey, 1991; Schulz & Bonawitz, 2007; Samarapungavan, 1992).

Driver et al. (1994) present a theoretical perspective on the construction of scientific knowledge. This perspective centers on how children learn science through both an individual construction of knowledge as well as through social interaction with peers and a teacher. What is highlighted in this theoretical piece is the importance or role of the science experience. The development of science ideas through personal experiences in students' daily lives requires "well-designed practical activities that challenge learners' prior concepts encouraging learners to reorganize their personal theories" (Driver et al., 1994, p. 5). Furthermore, children's early ideas about science change with additional experiences. From the research presented in this section of the review, students seem to acquire a vast range of ideas about science phenomena early in their lives. These ideas are developed through everyday experiences in the students' lives and appear to influence how they interpret subsequent science experiences. This suggests that the role of the science classroom is to provide early experiences that offer opportunities for students to build upon or challenge their prior ideas about science. For this reason Driver et al. (1994) argue that the intervention of the teacher (i.e., early formal science education) is absolutely essential to science education. Given the relative stability of early ideas about science, the emphasis on early science experiences in the elementary classroom is not trivial, but indeed a necessity for successful progress through science education.

## Early Interest in Science

Given the role of early experiences on the development of ideas about science, does the development of interest in science follow a similar timing trend? A significant collection of empirical evidence suggests that by age 15, students are less engaged in science than at earlier ages (Osborne, 2008). Prior to age 15, student interest in science is quite high with little difference between boys and girls (Murphy & Beggs, 2005). Thus, the research literature points to the idea that interest in science starts early. What follows is a review of empirical studies that investigate the timing of students' interest in science. Many of these studies suggest that the development of interest in science is early and that this interest has long-range educational outcomes (Tai et al., 2006). Some studies attribute early interest development in science with school-based experiences (Maltese & Tai, 2010) while others do not address the source of this interest and instead just show that the interest in science develops early (Hadden & Johnstone, 1982). Regardless of the studies perspective on the timing of interest, by age 14 an interest in science or lack thereof, is set in a majority of students (Osborne, 2008).

Tai et al. (2006) produced some of the most recent findings on the timing, development, and long-range outcomes of interest in science. Using the National Education Longitudinal Study of 1988 (NELS: 88), a nationally representative longitudinal data set, the study addressed questions pertaining to the importance of encouraging early interest in children's lives and how young students express an interest in science. The variables used for this analysis were the specific questions from the NELS: 88 surveys. Respondents were asked about their career expectations in eighth grade, which is at the approximate age of 13. Specifically, in what career did they see themselves engaged in at age 30? This expressed career interest was then used to predict the major or concentration of their undergraduate degree several years later. For the purposes of emphasis and clarity, the participants in the NELS: 88 study were asked to identify their age 30 career expectations while they were still in eighth grade. The multinomial logistic regression analysis showed that students who stated that they expected to have a science related career at age 30 while in the eighth grade were 1.9 times more likely to later earn a degree in the life sciences and 3.4 times more likely to later earn a degree in the physical sciences. Each of these odds ratios was relative to those students that did not express an expectation to have a science related career at age 30.

These results are particularly relevant to this study in that they clearly demonstrate that early interest in science is associated with the subsequent choice of college major or concentration. This persistence in science-related disciplines through college suggests not only that the development of interest in science begins prior to high school but also remains relatively stable through the high school years. Additionally, science-related experiences prior to eighth grade (i.e., elementary school) may have a significant influence on the development of science interest and thus career pathways in science. This implication of the study contributes most significantly to this review of literature. These findings refocus the importance of early interest development in science and make leaving early exposure to science to chance difficult or detrimental by not providing these experiences to elementary students.

In a subsequent study, Maltese and Tai (2010) used data obtained from interviews of current graduate students in physics or chemistry along with current physical scientists. The transcripts generated from these interviews were analyzed for the timing, source, and nature of the participants' earliest interest in science. The study found that 65% of those interviewed indicated that their initial interest in science occurred before middle school. 40% of the scientists and graduate students mentioned that the source of their initial interest was a school-based experience. Within these school based experiences, 24% stated that class content was the key source, 18% stated that demonstrations, laboratories, and projects were the source of primary interest, and 22% mentioned enrichment experiences in science. Maltese and Tai (2010) also noted a gender difference in their results. Specifically, female scientists and graduate students referenced school-based experiences (52%) more frequently than males whom more noted individually motivated interests (57%).

What is most interesting about these results is that the data comes from practicing scientists and graduate students, people who have persisted in science-related interests and have earned or are earning an advanced degree in a science-related field. Most notable is that a large percentage of these individuals indicated early timing and school-related experiences as their primary or initial source of interest in science. Thus, the lack of exposure to elementary school-based science experiences may actually be a missed opportunity for sparking the interest of future scientists. In particular, these results suggest that females may be most influenced by this lack of early exposure, which is not surprising given the current gender gap that exists within the physical sciences.

Prior studies by Cleaves (2005), Lindahl (2007), and Osborne, Simon, and Collins (2003) noted similar results in regard to early interest in science. Cleaves (2005) looked at post-16 choices of high achieving students in the United Kingdom based on their science course selection following compulsory education. In other words, this study looked at what would be analogous to post-secondary science course enrollment for academically strong students in the United States. The students were interviewed at four different points in their educational trajectory starting with age 13 or what is referred to as year nine in the United Kingdom. These semi-structured interviews about students' ideas related school subjects relative to interests, preferences, and thoughts about their future aspirations. Focusing on science subject choices beyond compulsory education, the authors looked for themes in student responses to develop different trajectories in science education. For example, students that constantly changed their ideas about school subjects, their own interests, preferences, or thoughts about their future were classified as a different trajectory from those students that maintained consistent ideas about these topics. Each trajectory was then associated with the secondary science course enrollment. In total, five trajectories were developed from the analysis of the interview transcripts, representing a continuum that ranged from completely stable views and beliefs to constantly changing beliefs from interview to interview. Cleaves (2005) found that students who maintained constant, stable beliefs about school subjects relative to interests, preferences, or thoughts about their future careers reported making post-compulsory education decisions with career ambitions in mind. Similar to the results from Tai et al. (2006), these students were committed to these ambitions at the beginning of the study, age 13. What is even more striking about these results is that those students that showed variability in their career ambitions attributed this variation to prior interests and preferences established prior to the first interview. For example, several student interviews suggested that the wavering in interest and preference towards science related courses was because of stereotypical beliefs or perceptions established well before the initial interview session. In other words, theses ideas about science had developed prior to age 13. Many of the initial interview responses pointed towards a general lack of understanding about science and thus a possible inhibitor to further pursuing science-related coursework. Cleaves (2005) suggest that this lack of understanding may be a result of the lack of exposure to science prior to age 13.

Lindahl (2007) looked at how attitudes about science changed overtime within a small group of Swedish students. A cohort of 80 mixed-ability students was followed from grades five through grades nine, participating in regular interviews. Along with regular interviews, participant observations were used to investigate the influence of classroom science experiences on both the attitudes about science and the long-range intentions of enrolling in higher-level science classes. Two of the findings from this longitudinal study suggest that students are thinking about their career intentions at an early age and that interest in science is a major factor in the persistence or continuation of study in the sciences. Interview data obtained from this study suggested that by age twelve many students are already thinking about potential careers in science related fields. More importantly to this review, the continued pursuit of those careers was most often attributed to interest in those fields. The qualitative outcomes of this study add further support to the idea that interest in science-related fields not only develops early, but seems to have a long-range influence on future courses of study and ultimate career decisions.

In 2003, Osborne, Simon, and Collins published a review discussing the body of literature on attitudes towards science. Although the link between interest and attitude is often debated and not clearly defined (Krapp, Hidi, & Renninger, 1992), the description of students' attitudes towards science and how these attitudes change over time, paint a similar picture to that of the previously discussed findings. For example, Hadden and Johnstone (1982, 1983) showed no significant change in student attitudes towards science from age nine onwards. These two studies followed a cohort of 1,000 students from 29 classes in 14 different primary schools in Scotland. Hadden and Johnstone (1982) developed an overall account of the development and nature of student interest in science using semi-structured interviews and a questionnaire composed of Likert-type rating items. The subsequent study (1983) followed the same cohort of students as they transitioned from primary schools to secondary schools and focused on the stability of students' interest in science. The transition from primary to secondary schools occurred at about age 11 or 12, which is analogous to the sixth or seventh grade in the United States.

In the initial study, appropriately referred to as the "years of formation", Hadden and Johnstone (1982) found that the development of interest in science occurred prior to the students' entering into secondary school (i.e., age 11 or 12). Compared with other subjects (e.g., arithmetic, 23.9% and geography, 28.5%) students were more interested and enthusiastic about studying science (44.4%) at the end of their primary schooling. The study further inquires about the development of interest and enthusiasm in science. 45% of the students indicated that they had an expectation of exciting, interesting new learning in science class. 2.3% stated that primary school activities sparked their interest and curiosity in science. These results are seemingly contradictory to the Maltese and Tai (2010) study that suggests school-school based experiences are the source of early, initial interest. However, beyond the obvious difference of the country of origin for these students, Hadden and Johnstone (1982) point out that in Scotland, most students have not received formal science instruction in the primary school and thus the source of interest cannot be expected to derive from school-based experiences. The absence of formal science instruction potentially explains why only 1.3% of Scottish students found science to be useful.

To clarify the benefit of including the Hadden and Johnstone (1982) study in this review, consider the follow-up study conducted in 1983, which sought to understand the stability and persistence of the high level of interest demonstrated in the primary school. Those students interested in science entered secondary school with a greater likelihood of enrolling in secondary school science courses. However, Hadden and Johnstone (1983) found that this interest quickly eroded during formal science instruction while in the secondary school. Specifically, the researchers observed a 17.7% decrease in the number of students that found science interesting to study. Along with this general decrease in interest, the study also noted the appearance of a gender gap with girls less interested than boys following the first year of science instruction in the secondary school.

Although these results seem outside of the scope of this study and generate questions well beyond those addressed in this review, these results must be placed in the context of the Scottish school system. With that in mind, the results suggest that the students in this study possess a natural interest in science. However, without early science experiences or formal school-based exposure to science prior to the transition to secondary schools, these students may be unprepared for secondary science. Hadden and Johnstone (1983) comment on the possibility that this erosion in interest can be attributed to the curriculum, assessments, teacher, and or school environment. In other words, that natural interest alone is not enough for later success in science. Early and formal school-based preparation may actually develop readiness for later science education in the secondary schools. Yet, the study does not address those issues directly.

Research studies from both the United States and the United Kingdom highlight a similar decline in interest and attitudes towards science beyond age 11 (Breakwell & Beardsell, 1992; Daugherty & Dawe, 1988; Yager & Penick, 1986). The erosion of early interest is not exclusive to the students in Hadden and Johnstone's studies (1982; 1983). Short of accusing secondary schools of ruining student interest, this does not provide a positive outlook for the fate of students with an early interest in science. However, Osborne, Simon, and Collins (2003) suggest in their review of this body of literature that students possess a disparity between their notions of science early on and what these students actually encounter in science class beyond age 11. The relevance of this discussion lies in both the importance of early experiences in science as well as the nature of those experiences. Instead of immediately placing the blame of this erosion on secondary schools in the United States, United Kingdom, or Scotland, to find a solution it may be more productive to look at the early exposure to science and how it is associated with the development of this early interest. Are students offered experiences that contribute to the development of this early interest? In other words, not providing school-based early experiences, as in Hadden and Johnstone (1982), can be detrimental to student achievement even when an early interest is present (i.e., Cleaves, 2005). Although early interest is a key component of later involvement in science-related disciplines, early interest in the absence of early science experiences may produce an entirely different effect.

Pre-dating most of the studies in this review, Hodson and Freeman (1983) also found that the literature indicates interest in science develops early. This conclusion continues to be in agreement with studies published after 1983. Hodson and Freeman (1983) also point out that these same studies often find that the most significant factor in subject-choice in school is student interest. Although not an empirical research study, these authors present a review of the research along with a list of problems associated with investigating early or primary science interest. These issues are: the measurement of interest is difficult in the early years given that not all elementary students have equal access and exposure to science; the variation in the nature of these early science experiences from school to school and classroom to classroom is extremely large; many of the previous studies ignore the influence of gender; finally, interest in science is often assumed to be associated with general intelligence. Before a research study can appropriately address any question about early experiences and early interest in science, these challenges must be met. The research questions presented in this study are not only supported by this review of literature, but these questions take into account each of the problems cited by Hodson and Freeman (1983) that have haunted prior work in this area of science education.

In sum, the literature supports that early interest plays a significant role in the continuation of students in science education (i.e., Tai et al., 2006; Maltese & Tai, 2010; Cleaves, 2005; Hadden & Johnstone, 1983; Hadden & Johnstone, 1982). In addition, the literature suggests that early experiences in science are vital to the science education of young students by promoting early interest (i.e., Driver, Asoko, Leach, Mortimer, & Scott, 1994; Stein & McRobbie, 1997). It would seem, then, that the next logical question is, how do early experiences and interest in science influence achievement in science?

## Interest and Achievement

The inclusion of interest and achievement in this review is twofold. First, earlier success in both mathematics and science courses influence course-choice in high school mathematics and science. Secondly, success in these courses in secondary schooling ultimately determines later opportunities with regard to colleges and or career selection (Hadden & Johnstone, 1983). Taken together, a student's interest as manifested by later course selection also depends on his or her success in those courses. In the end, knowing how student interest is associated with achievement is valuable in understanding the education trajectory and the implications of this trajectory on long-range student outcomes. Tobias (1994) asserts that students who are interested in a particular subject are more likely to spend more time devoted to that subject and thus acquire more knowledge about that particular subject. In this case, Tobias (1994) views interest from the standpoint of time devoted to a particular subject. So then, does interest in science influence academic achievement in science?

Singh, Granville, and Dika (2002) used data from NELS: 88 to develop a structural equation model (SEM) to investigate behaviors and attitudes of eighth graders that are associated with academic achievement in science and mathematics. Selecting a random sample from the original NELS: 88 population, 3,227 student respondents were included in the study. The SEM model was developed using interest variables, mathematics and science grades, and standardized test scores in mathematics and science. This study developed latent constructs for interest, motivation, and attitudes based on behavioral indicators collected in the NELS: 88 data set. For example, questions about how often a student attended/skipped class or how frequently a student attended class without pencils, books, or homework were used to develop a construct around participation and preparedness and were used to develop a latent construct of motivation. Likewise, questions about excitement and enthusiasm towards attending science or math class were used to develop a latent construct of interest.

Two separate models were developed, one for mathematics and one for science. What is discussed in this review is the SEM model for science achievement. Singh, Granville, and Dika (2002) found that motivation, student attitudes towards science, and the level of active engagement in science class significantly influenced science achievement. Additionally, the latent construct of academic engagement contained variables associated with time spent on science learning (i.e., homework, reading, studying, etc…). The body of literature associated with interest often focuses on sets behaviors that would indicate interest (Osborne, Simon, & Collins, 2003) and will appear later in this review. This is important in that Singh, Granville, and Dika (2002) found that the amount of time devoted to science by these eighth graders was the strongest predictor of their science learning and achievement.

Prior research suggests that the amount of time a student devotes to a particular subject is associated with the student's achievement in that subject area (Good, 1983; Good & Beckerman, 1978). Looking at a decade of classroom research (i.e., the 1980's), Good (1983) highlighted the wide range of variation in the amount of time students are engaged in specific content. Similarly, Good (1983) points out that moderate correlation exists between student engagement and achievement. For example, Good and Beckerman (1978) found that high achieving students spent more time on task and devoted more time to academic subject than medium or low achieving students. This naturalistic study looked at sixth grade engagement based on academic achievement in various school content areas. Three schools were selected in this study that included equal proportions of girls and boys as well as a wide range of socioeconomic statuses. The students were observed in various, natural settings in sixth grade classrooms. These settings included whole-group, small-group, and teacher-led activities. The observations were coded based on the level of engagement and the content discussed within the setting. The outcomes of this study suggest that student interest leads to more devoted time on task, which in turn is associated with higher achievement.

A more recent study by Reynolds and Walberg (1992) looked at achievement and attitude in $11^{th}$ grade science students. Using a sample of 2,535 students from the Longitudinal Study of American Youth (LSAY), Reynolds and Walberg (1992) developed a structural model that contained nine productivity constructs around science achievement. Two of these constructs, which are most relevant to the current review, are science attitude and prior science attitude. For both of these constructs, student interest in science is a key component of the latent variable. When placed into the structural model, the model results suggest that prior interest in science has a direct effect on prior achievement. However, this prior interest does not appear to have an effect on later achievement in science. What these results suggest is that to sustain interest and later achievement in science, students must experience positive achievement outcomes for the persistence of interest. This aligns with expectancy-value theory often cited in psychology when discussing achievement motivation (Wigfield, 1994). As stated differently by Reynolds and Walberg (1992) "higher levels of achievement may enhance self-perceptions of ability, thereby leading to greater appreciation and interest in particular subject matter, such as science" (p. 381). Yet, this model of achievement and interest appears to begin with early interest, leading to early achievement that then gravitates towards the results presented in this discussion. Pintrich, Marx, and Boyle (1993) describe the interaction of interest and achievement as learners having intentions, goals or purposes that influence their learning. Again, this particular study provides a glimpse into the complexity of the factors associated with science achievement and yet how dependent these factors are on early interest and achievement.

A study in 1996 provided some clarity into the interaction between interest and science achievement (Young, Reynolds, & Walberg, 1996). Using achievement test scores and multiple individual factors for 2,535 tenth grade students participating in the LSAY study, these researchers looked at the influences on science learning and achievement. The sample population for this study was the same population in prior work by Reynolds and Walberg (1992). However, this study used hierarchical linear modeling to address the variance associated with students nested within classrooms and classrooms nested within schools. This multi-level model indicated that student-level factors (e.g., attitude toward science, prior science achievement) accounted for 37.4% reduction in the variance associated with the dependent variable, science achievement. Of those factors, prior student ability and attitude towards science were the most significant student-level predictors. Young, Reynolds, and Walberg (1996) point out that these results suggest the inclusion of prior achievement and interest variables when investigating subsequent science achievement. Research supports the significance of association between science interest and achievement.

Taken together, the existing body of research suggests that interest in science is associated with achievement in science in so far as interest manifests itself as time devoted to science learning. Although the complete nature of this association is unclear beyond the earliest years of schooling, the literature makes the existence of such relationship tough to deny. Using a meta-analytic approach, Schiefele, Krapp, and Winteler (1992) reviewed the collection of research since 1965. Obtaining 121 independent correlation coefficients for studies investigating the effect of interest on academic achievement, all correlation coefficients were found to be positive and ranged from .09 to .67. For science, the average weighted correlations were .35, .31, and .16 for general science, physics, and biology, respectively. Although this particular meta-analysis only included correlational studies, it does emphasize the relationship between interest and achievement and further advocate for the development of early interest in science through early experiences. These early experiences and development of interest may lead to positive achievement outcomes for science students. Schiefele, Krapp, and Winteler (1992) cautiously point out that more work is needed in this area with regard to other contributors (i.e., gender and age) and that many studies fail to look at the interaction between these two variables. In other words, does gender or SES play a role in the interest and achievement dynamic?

## Demographic Influences on Science Achievement

### *Gender*

The role that gender plays in science achievement is most commonly linked to the persistent gender gap that exists in the sciences (Brotman & Moore, 2008). The "gender gap" present in the sciences has been the topic of much conversation, debate, and research over the past several decades. Specifically, the underrepresentation of females has evoked a collection of research literature looking at both the causes and possible solutions to this gap (Scantlebury & Baker, 2007). One perspective on this issue is that gender differences in the sciences are not accounted for by ability differences but are spawned by other factors related to the differential experiences of males and females in science (Bleeker & Jacobs, 2004; Spelke, 2005). What follows from these differing experiences is an influence on student motivation and interest as well as perceived competence (Andre, Whigham, Hendrickson, & Chambers, 1999; Baker, 1998).

Gender differences in interest, motivation, and perceived competence appear to exist in middle school students (Beghetto, 2007). Although most believe that these differences exist in the elementary school, very little work focusing on interest, motivation, and perceived competence exists for science. One such study by Andre et al. (1999) reported that kindergarten through eighth grade girls reported having less competence in the physical sciences even though they also reported enjoying science class. This difference only existed for physical science, as there was no difference reported for the life sciences (Andre et al., 1999). Surprisingly, studies on sex differences in perceived competence exist for other disciplines such as reading, math, and music while virtually non-existent for early childhood and elementary science (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). Although not specific to elementary school students, studies describing the level of interest and the nature of attitudes towards science provide insight into the differing attitudes towards science between girls and boys and are certainly worth mentioning. Collectively, girls tend to have less positive attitudes towards science, these attitudes decline significantly with age, with girls perceiving science as uninteresting, too hard, and leading to a less than desirable lifestyle, and finally, with girls perceiving themselves as having less competence than boys in science class (Reid, 2003; Miller, Blessing, & Schwartz, 2006; Andre, Whigham, Hendrickson, & Chambers, 1999; Jovanovic & Steinbach King, 1998). Yet, opposite findings have been reported and indicated that some girls have positive attitudes, feel confident and competent, and also have a positive view of women engaged in science (Harwell, 2000). In addition, some studies point out that girls prefer the biological sciences, have a preconceived notion that the physical sciences are for boys, and that boys are more likely to participate in extracurricular events (Dawson, 2000; Miller et al., 2006; Andre et al., 1999; Catsambis, 1995). What is absent from these back and forth of findings and results is an explanation for why certain girls have negative attitudes and lower feelings of competence while others report positive attitudes and feelings of competence equal to that of boys.

Are boys and girls treated differently in the classroom? Do these inequities influence achievement in science? What research exists on these younger science learners' focuses on equity and access, gender-sensitive curricula, the nature and culture of science, and identity development (Brotman & Moore, 2008). Again, many of the studies addressing access and equity focus on age groups above and beyond elementary school students (i.e., Catsambis, 1995; Bailey, Scantlebury, & Johnson, 1999; Miller, Blessing, & Schwartz, 2006). The studies focused specifically on elementary school students and their experiences indicate a difference in how boys and girls engage in hands-on activities and science equipment as well as the response and interaction with the classroom teacher. In a study by Jovanovic and Steinbach King (1998), the participation of girls and boys in hands-on activities was measured using observation and checklist protocols as well as closed-end questionnaires. The results indicated that boys tended to manipulate laboratory equipment more often than girls (Jovanovic & Steinbach King, 1998). However, looking at students from a K-12 school in Hawaii, researchers found that girls and boys manipulated science equipment the same amount, but the girls received less attention than the boys (Greenfield, 1997).

With regard to access and equity, the classroom environments for early childhood and elementary science may play a significant role in the shaping of attitudes, motivation, and feelings of competence that are often reported in studies focused on middle and high school students. This seems more than reasonable, given the body of research on early interest in science (i.e. Tai et al., 2006; Maltese & Tai, 2010). Thus, obtaining a comprehensive view of what an early childhood and elementary science classroom looks like may provide better insight into what experiences influence these attitudes, motivation, and competence based outcomes. The research supports the assertion that positive attitudes, motivation, and perceptions of high competence are strong predictors of future science achievement (Nieswandt, 2007; Eccles, 2007; Simpkins, Davis-Kean, & Eccles, 2006). The focus on gender has spawned a body of research on what these early science classrooms should look like and what gender-inclusive practices entail (Baker, 1998).

Gender-sensitive curricula involves deliberately linking science content with the everyday experiences of females, providing ample opportunity to explore the social applications of science, link science to domestic and nurturing aspects of life, and presenting the role of women in science (Brotman & Moore, 2008; Baker, 1998; Eccles, 1997; Baker and Leary, 1995). What is most interesting about gender-sensitive curricula is that it has shown gains in both girls and boys in motivation (Patrick, Mantzicopoulos, & Samarapungavan, 2009). In addition, a study of fourth and fifth graders reported the elimination of the gender gap in motivation following a gender-inclusive practice. Specifically, the activity involved an activity-based unit on electricity (Kahle, Parker, Rennier, & Riley, 1993). Explanations of the effectiveness of gender-inclusive practices like the one described above are based on studies such as Jones, Howe, and Rua (2000) which report that girls are more relational, follow directions where as boys were more competitive and tinkered and explored more with the science materials. Thus, activity-based cooperative learning activities that require the parsing out of responsibilities may be more conducive to gender-inclusive science learning. Furthermore, a study by Johnson (1999) indicated that kindergarten girls are offered three times more opportunities to participate in life science activities compared to physical science activities. Offering girls more opportunities to write about science and their experiences with doing science may inspire more interest, motivation, and competence as girls are more often described as been more proficient at expressing their ideas, thoughts, and experiences in written form (Warwick, Stephenson, & Webster, 2003). As an aside, studies focusing on gender differences at the high school level (see Labudde et al., 2000) show no reduction in the gender gap further emphasizing the importance of early childhood and elementary school experiences.

Aside from classroom experiences and gender-inclusive practices, the images of scientists that students have seems to contribute to their ability to see themselves as a scientist and thus interest and motivation to learn science (Brotman & Moore, 2008). For example, the study of 1,000 students from five schools in England all between the ages of four and eleven investigated the images of scientists held by these students. The students were asked to draw a scientist at two different times, six years apart. At both drawings, most students drew a male scientist (Newton & Newton, 1998). This study suggest that the way in which scientists are portrayed in classrooms has an impact on whether students can see themselves as practicing scientists especially girls. This belief or development of identity can play itself out in multiple areas. For example, Ford, Brickhouse, Lottero-Perdue, and Kittleson (2006) looked at girls' access to and choices of science books. In this study, girls had access to science books and had a preference for a particular area of science books. However, the study also found that parents underestimated their daughters' interests and did not support this desire to read science books (Ford et al., 2006). The reluctance for girls to identify with a scientist may be hindered or augmented by the environment in which they learn science.

In sum, the research literature suggests that gender differences do exist in the sciences. What is debatable, as evidenced by the spectrum of literature on the topic, is the nature of these differences and the root cause of these differences. These differences appear not to be the result of ability (see Bleeker & Jacobs, 2004; Spelke, 2005), but a product of the environment in which these students first encounter and experience science. Also worth noting is that those interventions in secondary classrooms seeking to eliminate the gender differences are not successful (see Labudde et al., 2000). Capturing the nature of early childhood and elementary experiences in science with equity, access, gender-inclusive practices, and overall identity in mind may provide the most fruitful information for addressing these differences in interest, motivation, and perceived competence. What makes this issue particularly complicated is the mixture of published results citing both positive and negative outcomes as well as the strictly dichotomous gender grouping (Brotman & Moore, 2008). In other words, looking at girls in science without looking at within-group characteristics may not be helpful, just as assuming all girls are the same is not a fair assumption. For example, Kahle and Meece (1994) identified individual, socio-cultural, family, and educational variables that exist within gender groups, potentially making the description of females too broad, and therefore, not particularly helpful in addressing the issue of underrepresentation and gender gap.

*Race, Ethnicity, and Socioeconomic Status*

The body of literature focusing on race, ethnicity, and socioeconomic status (SES) is often presented in combination and not as separate variables. Instead, many studies compare mainstream versus nonmainstream student populations where mainstream populations are composed of white, middle or upper SES, and native speakers of Standard English and nonmainstream students are students of color, low SES, and speak English as a second language (Lee & Buxton, 2008). One exception to this is a study by Buck, Cook, Quigley, Eastwood, and Lucas (2009) which utilized a mixed-method approach to understand the attitudes of urban, low SES, African-American girls towards science. The motivation behind this study was to expand the current body of literature from being solely gender focused to exploring the gender variable across race and SES (Buck et al., 2009). The outcomes for this study indicated for orientations associated with urban, low SES, African-American $4^{th}$, $5^{th}$, and $6^{th}$ grade girls: high confidence/high desire, high confidence/low desire, low confidence/high desire, and low confidence/low desire. In addition, the study's authors noted that this targeted, nonmainstream group was extremely diverse in and of itself, further condemning the approach of treating these groups as homogenous. Thus, the challenge of addressing issues of race, ethnicity, and SES is similar to that of gender in that diversity within groups often makes it difficult to address group differences.

Lee and Buxton (2008) refocus the issue by looking at equitable learning opportunities. They point out "research has shown that, when provided with equitable learning opportunities, students from diverse backgrounds can learn challenging science curriculum and achieve a range of science outcomes" (Lee & Buxton, 2008, p.124). More specifically, these authors focus on curriculum and what must be considered by curriculum development teams if equitable learning opportunities are to be provided to the diverse student populations (i.e., nonmainstream learners). The purpose for addressing the Buxton and Lee piece in this review is that it provides a framework for evaluating the impact of science curricula on the nonmainstream group of science learners. In other words, what is the impact of curricula on addressing the achievement gap that is commonly linked to low SES and minorities? What issues must be addressed by a curriculum to meet the needs of a diverse student population? What does a culturally responsive curriculum look like or have to include?

Positive gains in science achievement have been linked to culturally responsive curricula. For example, Aikenhead (2001) investigated the implementation of a curriculum that provided cultural context to First Nations groups. An increase in student participation was observed by informal classroom assessments (Aikenhead, 2001). Likewise, Matthews and Smith (1994) utilized a pretest-posttest design to assess the impact of a culturally responsive curriculum for Native Americans. Both higher achievement scores and an increase in positive attitudes is noted (Matthews & Smith, 1994). Similar evaluation studies have been done with curriculum designed for those students learning English as their second language (Fradd, Lee, Sutman, & Saxton, 2002; Lee, Deaktor, Enders, & Lambert, 2008; Cuevas, Lee, Hart, & Deaktor, 2005). What makes these studies unique is that they address the problem by combining literacy and science. Culturally responsive curricula appear to focus on inquiry, the integration of the English language with scientific literacy, as well as the incorporation of the primary language of these learners. Positive gains in science and literacy achievement have been reported (Fradd et al., 2002; Lee et al., 2008; Cuevas et al., 2005). Given that the achievement gap between different races and ethnic backgrounds may start earlier than expected (see Chapin, 2007), infusing science literacy into language instruction may be a potential solution to closing this achievement gap.

Increasing access to and the use of technology for racial and ethnic minorities has also been addressed in the literature (Lei & Zhao, 2007; Weaver, 2000). However, many of them have focused on middle school and high school student achievement in science and have shown to be positive effects. Chang and Kim (2009) used the Early Childhood Longitudinal Study (ECLS) to look at the effects of access and usage of technology on those elementary students learning English as a second language with science achievement as the outcome variable. However, these results were not similar to the studies on middle school and high school students. Instead, students learning English as their second language indicated a negative effect (Chang & Kim, 2009). The negative association is comparatively stronger for Hispanic and non-English speaking students, suggesting a language component in the access and use of technology. It should be quickly noted that these results are not the same for studies focusing on low SES environments while controlling for race and ethnicity. This will be addressed in the discussion on SES and science achievement.

Overall, the body of literature that addresses the racial and ethnic components of science education shares a common theme with the gender research. First, it recognizes that there is indeed an achievement gap. Secondly, it does not automatically attribute that gap to ability. Instead, it focuses on equitable learning opportunities through either culturally responsive curricula or in the case of gender, gender responsive curricula. What a culturally responsive curriculum looks like will more than likely vary depending on the particular cultural.

In general, socioeconomic status (SES) has been linked to student achievement. More specifically, indicators of the level of SES such as parental education, income, home environment, intellectual stimulation, and home resources seem to be strong predictors of student achievement (e.g., Campbell & Wu, 1994; Iverson and Walberg, 1982; Xin, Xu, & Tatsuoka, 2004; Chang, Singh, & Mo, 2007; Lee & Buxton, 2008; Buck et al., 2009).

Iverson and Walberg (2002) prepared a synthesis of research looking at the influence of home environment on school learning. Although this particular synthesis did not address science education specifically, it provided a general overview report of correlations between school learning and home environments. The take home message presented in the review is that parent-child interactions are better measures of home environment and thus school learning outcomes than parental attitudes, habits, and beliefs (Iverson & Walberg, 2002). In addition to attitudes, habits, and beliefs, academic ability and achievement seems to be more closely linked to the socio-psychological environment and intellectual stimulation rather than parental occupation and income (Iverson & Walberg, 2002). This suggests that parent-child interactions and the nature of the home or out-of-school learning environments are more satisfactory predictors. It also appears that more work in this area, especially studies with regard to the nature and substance of interactions or the necessary components of an intellectually stimulating environment is needed. Research literature on poverty suggests that students brought-up in an impoverished environment often have significantly few parent-child interactions (Duncan & Brooks-Gunn, 2000). Xin, Xu, & Tatsuoka (2004) found that this intellectual stimulation and home environment may transfer to the classroom environment via teacher selection. The multi-level model presented in their study indicated that between-teacher variance was reduced when family and background factors were included. They suggest that students from higher SES are actually matched with better teachers (Xin, Xu, & Tatsuoka, 2004).

The challenges faced by those of low SES are often due to lack of resources and funding that trickle down to a lack of appropriate science materials or supplies, decreased access to technology, overcrowding of schools, and management issues associated with socio-psychological issues (Knapp & Plecki, 2001; Spillane, Diamond, Walker, Halverson, & Jita, 2001). Judge, Puckett, and Cabuk (2004) and Judge, Puck, and Bell (2006) used the ECLS to look at the differential access to computers in high versus low poverty environments. More specifically, students' access and use of computers was related to the SES status of the school (Judge, Puckett, and Cabuk, 2004). What is disconcerting about this finding is that earlier reports indicated that 99% of all public schools had access to the internet (Kleiner & Farris, 2002). Yet, the access to technology was not as robust. Given that technology is often cited as a means for increasing interest and opportunity to learn science, the relationship between SES and technology would seem to indirectly influence science achievement. A second conclusion to the 2004 study is that home access is also significantly limited for high-poverty schools (Judge, Puckett, & Cabuk, 2004). Given that schools are initial access points for computer access and use, it appears less supported in the homes of lower SES families. The follow up study looked at mores specific variables associated with computer access and use and general academic achievement (Judge, Puck, & Bell, 2006). Overall, access and use of a home computer, computers in the classroom, frequent internet access, proficiency in computer use, and low poverty status are all positive correlated with general academic achievement (Judge, Puck, & Bell, 2006). This suggests that technology plays a role in achievement, but this role is mitigated by the SES status of the school. However, it would seem that a high-poverty school would benefit from these results in that it suggests what resources, as limited as they may be, might provide the most beneficial outcomes with regard to technology. Schools that are able to successfully identify, activate, and bring together resources provide the best opportunities for leading and implementing change (Spillane et al., 2001).

The literature focusing on the role of SES in student achievement is as expansive as the range of variable associated with SES. Given that SES involves a multitude of indicators, measures, and characteristics (i.e., parental income, home environment, intellectual stimulation, and lack of resources), composing a comprehensive or complete view of SES impact on general achievement is challenging and more so in examining science achievement specifically. In fact, there is a paucity of literature that addresses just SES and science achievement. This is understandable. The significant impact of low SES on so many other aspects of student learning (e.g., reading, literacy, and mathematics) makes science achievement only a small piece of the puzzle. However, the research that does address this impact on general achievement also provides useful and highly relevant information to the teaching and learning of science. What is clear from this review is that SES influences many variables that are vital to the development of science literacy and proficiency.

## Duration and Frequency of Elementary Science Instruction

The importance of duration and frequency on any achievement outcome seems both obvious and valuable. In other words, the longer the amount of time or an increase in the frequency of time spent on a specific academic area, the greater the achievement outcomes. However, the research literature surrounding duration and frequency is less than clear on the role the two concepts play in academic achievement. Disconnect in the literature seems to be attributable to three issues. First, much of the research has focused on time spent on a subject rather than parsing out the differences between time spent and how often (e.g., Walberg, Fraser, & Welch, 1986; Betts, 1987; Figlio, 1999). Secondly, the definition of time spent varies from study to study. For example, Betts (1997) used time spent on mathematics homework as a measure of instructional while Walberg et al. (1986) used the number of semesters a student spent in high school science. To compound this issue and certainly a more relevant issue for this review is that these measures are often utilized in studies of upper level students (i.e., grades 8-12) and on disciplines other than science. Finally, there is disconnect between duration, frequency, and achievement outcomes in that these variables and their relationship to achievement are not even included in most analyses (Coates, 2003). The most recent attempt to measure duration and frequency with regard to achievement utilized multiple measures in combination (Dewey, Husted, & Kenney, 2000). This particular study included the number of minutes spent in class during the day, number of school days, in addition to the number of hours spent studying outside of school, and also accounted for days absent or time away from school.

One recent study found that science activities occupied 11% of the time in a fifth grade classroom. Pianta et al. (2007) found that when compared to the 17% of time allotted to instructing students on managing materials and time, this figure is even more alarming. This epidemiological study investigated the elementary school classroom experiences of 2,500 students from approximately 1,000 classrooms across a multitude of schools and school districts (Pianta, Belsky, Houts, & Morrison 2007). The focus of the study was on teacher behaviors, student activities, and the instructional setting across multiple time-intervals during the school day. In addition to the diminished amount of time devoted to science instruction, the outcomes of this study also suggest that the opportunities to learn provided for the students were not consistent with expectations or high standards associated with elementary schools in the United States.

The results reported in Pianta et al. (2007) are consistent with earlier work by Good (1983). In a review about the progress of classroom research, the data associated with time usage in elementary schools indicates that approximately 50-60% of the elementary school day is used for instructional purposes. In light of that percentage, many studies reported that on average, as little as fifteen minutes per week were spent on science instruction during second through sixth grade (Good, 1983).

The study of duration and frequency is further complicated by investigating how time is spent rather than just the quantity of time spent on a particular academic area (Reimers, 1993). In other words, a cofounding issue with looking at time spent on a subject area is the quality of that time. Brown and Saks (1986, 1987) found that the initial achievement levels interacted with the amount of instruction time spent on a particular area as well as significant between teacher variance in the outcomes. Rowan, Correnti, and Miller (2002) used data from large-scale survey to look at both the minutes spent per week on reading and mathematics as well as the percentage of time spent actively using various strategies. The results were mixed along the different strategies as well as across students. Other studies have reported that no instructional time variable was statistically significant and often interacted with class size (Coates, 2003). This suggests that how time is spent and the make-up of the particular classroom plays a role in the relationship between duration, frequency, and achievement. What is missing in the literature is the influence of individual student factors as well as the time spent on one subject and the association with performance in another subject (Coates, 2003). Thus, study of duration and frequency in isolation of other cofounding issues (i.e., quality of time, class time, and performance in other subjects) may mask the findings of such research studies.

The above discussion provides a glimpse into the general body of literature on time spent on academic content. As mentioned previously, the literature often approaches time spent from multiple definitions or fails to look at the cofounding variables that may influence the results (e.g., quality of time spent, student factors, time spent on one subject and the performance in another subject). Specific to science, the body of literature is even scarcer. Using data obtained from the Programme for International Student Assessment (PISA), Baker, Fabrega, Galindo, and Mishook (2004) found that on average, instructional time spent in science accounted for 5% of the variance in science achievement. Although small, the authors note that science was unique in that science instructional time was not associated with lower achievement for any country in the study (Baker et al., 2004). Outside of the United States, studies looking at the relationship between instructional time and science achievement have indicated a positive relationship. When science instructional time was measured in daily hours or days per year, students in Thailand, India, and Iran showed positive gains in science achievement with increased time spent in science (Fuller, 1987; Heyneman & Loxley, 1983).

In Coates (2003), minutes of instruction across multiple content areas were evaluated against reading, mathematics, and writing achievement. Extracting the science component of this study indicated that an increase in science minutes of instruction produces results similar to the ones discussed above. First, increase in science minutes is not individually significant. Furthermore, science class-size and instructional time interaction is not individually significant. Instead, increasing minutes in science seems to correlate positively with writing scores and reading scores (Coates, 2003).

More work in this area is necessary to better understand the impact of instructional time on student science achievement. What is even more apparent is that simply looking at time may not be as informative unless additional aspects of instructional time are included in the study. For example, some of the studies discussed above include complementary content areas as well as how the time in science class is spent. If teachers do have an increased amount of time or frequency for teaching science, what are they doing with that time? In addition, each of the studies discussed here look at a snap shot of the relationship between the amounts of time spent on science and science achievement. As earlier pointed out in the assumptions associated with this study, this approach ignores the fact that science achievement is the cumulative result of science instruction over multiple years of formal science education. Again suggesting that a more expansive look at the frequency, duration, and time devoted to science is necessary.

## Avoidance of Teaching Elementary Science

Research indicates that elementary classroom teachers are avoiding the teaching of science (Goodrum, Hackling, & Rennie, 2001; Osborne & Simon, 1996). During the last phase of a three-phase study, Harlen (1997) interviewed 33 teachers by telephone about their teaching of science during a ten-week period. This study identified six strategies used by teachers to avoid teaching science: outright avoidance, only teaching science content that the teachers were comfortable with, stressing process over content, relying on pre-packaged curricula, using only lecture while avoiding questions or discussion, and finally, only using the simplest of activities to avoid things going wrong. Harlen (1997) also point out that these avoidance behaviors interact with teacher's classroom practices in such a way that teachers do not see science instruction as a problem. For example, a teacher that addresses only content that he or she is comfortable with will more than likely not identify that he or she has a problem in that area. In light of evidence that suggests teachers self-reports on their own teaching practice differs significantly from observational data obtained from an outside observer (see King, Shumow, & Lietz, 2001), the issue of avoidance, as well as duration and frequency may be under-reported.

Specific avoidance behaviors have different implications. Teachers that avoid teaching science content outright or only teaching content with which they are most comfortable obviously leave parts of the curriculum untouched. Assuming that science was taught with adequate duration and frequency, these students would still be missing out. Using pre-packaged materials or curricula implies a different set of learning experiences. Relying solely on the textbook is often associated with an emphasis on vocabulary learning and the memorization of facts (Mastropieri & Scruggs, 1994). What activities do exist with these textbook based curriculums does not truly represent authentic science (Chinn & Malhotra, 2002).

The avoidance behavior of using only lecture while avoiding questions or discussion speaks to the overall quality of early science instruction rather than just the quantity. In this case, students' exposure to early science instruction may not be beneficial even though time has been allotted for such instruction. With regard to lecturing or expository teaching, the literature supporting or refuting the use of expository teaching when compared to other methods (e.g., laboratory methods, inquiry) is often contradictory and thus not helpful. As far back as 1971, researchers were looking at the relative effectiveness of the expository method versus the laboratory method and the discovery method (Babikian, 1971). However, literature does exist on other methods for teaching elementary school science that highlights the need for a variety of approaches such as inquiry, conceptual change, cognitive conflict, small group interaction, and models and analogies, and writing or science notebooks rather than limiting science lessons to expository teaching (Carter, Jones, & Rua, 2003; Barnett & Moran, 2002; Tomkins & Tunnicliffe, 2001).

Duration, frequency, and avoidance of elementary school science teaching is clearly an issue that likely plays a role in science achievement. However, research directly addressing the impact on achievement is scarce. One of the reasons for this scarcity may be due to disconnect between teachers self-reports and direct observations of practice as reported by King, Shumow, and Lietz (2001). Another reason may be the existence of mandate curricula and benchmark or standardized assessments (Lee & Houseal, 2003; Marx & Harris, 2006). The signing of No Child Left Behind (2001) brought increased focus on standards as well as measures of accountability and assessment into public education. Much to the disappointment of many, science was not an initially a tested content area. No standardized science assessment coupled with the increased emphasis on literacy and mathematics may have pushed both elementary science teaching aside as well as certain variables within the research on elementary science teaching (Marx & Harris, 2006). However, with the less than stellar news from the National Science Board mentioned at the beginning of this review and the implementation of a science standardized assessment in 2007, a renewed interest in early childhood and elementary science may have arrived. This discussion moves beyond the purpose of this particular review but a discussion worth broaching. What is important is the need for more research on the association of the duration, frequency, and avoidance of elementary school science with subsequent achievement and interest in science. As mentioned several times before, this research should look at multiple years of science achievement to gain a more robust picture of students' trajectory in light of the allotted time for formal science instruction.

## Interest as Behaviors in the Science Classroom

What does interest in the science classroom look like in terms of the students level of engagement? The behavioral manifestation of interest is not clearly defined or explored in research literature. However, multiple theoretic discussions have emerged to provide a framework for the discussion and exploration of student interest and associated behaviors. One such theoretical model asserts that individual interest manifests itself in two distinct ways: a dispositional state and an actualized state (Krapp, Hidi, & Renninger, 1992). Dispositional interest is described as a set of stable characteristics and or feelings towards a particular subject area, object, task, or situation. Individual interest as an actualized state tends to manifest itself as a set of observable behaviors such as focus, effort, time dedication, persistence, and active engagement (Deci, 1992; Penzel, 1992). Hidi (2006) defines interest as “an enduring predisposition to re-engage with particular content such as objects, events, and ideas (p. 70). Almost all theories and definitions of interest assume that interest and subsequent actions originate from exposure to a particular environment, in this case, early science experiences (Wade, 2001; Hidi & Renninger, 2006). This assumption provides the strongest argument for including a discussion on interested and associated behaviors in this review. By investigating an individual’s interest and motivations, why that individual engages or disengages in a particular subject area, object, task, or situation may be more apparent (Eccles & Wigfield, 2002).

Prenzel (1992) describes one manifested behavior associated with interest as the persistence of an individual within a particular domain or task. Once an individual becomes interested in a particular domain or task, that person needs no other reason to repeatedly engage in that activity and all other behaviors associated with that activity. This is defined as selective persistence (Prenzel, 1992). As mentioned previously, the work in this area is highly theoretical and virtually absent of any empirical work. Many researchers have contributed large amounts of literature to the theoretical construction of the origins and manifestation of persistence (i.e., Allport & Vernon, 1931; Berlyne, 1978; Hunt, 1965; Maehr, 1976; White, 1959). Each of these theoretical works possesses two similar characteristics. First, persistence is found in the interaction between people and various domains. With regard to this review, the interaction between students and science would potentially foster persistence in behaviors associated with learning science. Secondly, it is described as repeated activity within a particular domain. Thus, looking at student's activity in the science classroom may serve as an indicator of his or her selective persistence and therefore interest level in science.

Empirical work in this area, although scarce, focuses more on general interest rather than domain-specific interest. Renninger and Wozniak (1985) looked at the interests in young children between the ages of two and five. This naturalistic look at preschool indicated that the young child's interests were positively associated with students' attentional shift, word recognition, and recall. More specific to this review, students persistently shifted their attention to objects (e.g., bear, doll, horse, play dough, train, purse) about which they had the most interest. Likewise, children were more likely to engage in play with that toy more frequently and over longer periods of time.

Prenzel (1992), in one of the few domain-specific studies, conducted an exploratory study with two domains, computers and music. Twenty-seven individuals were assessed on their level of interest in computers or music. Interviews and recorded sessions were used to determine the nature of the engagement between the individuals and one of the objects (i.e., a computer or guitar). The interviews provided insight into the thoughts and feelings about the engagement with either of the two objects. In the end, Prenzel (1992) found that the degree of interest influenced the level of persistence as well as the feelings towards the engagement activities. For example, the level of enjoyment, the flow of the engagement activity, the feelings of competence with the object, as well as the cognitive conflict experienced varied depending on how interested the participants were in that object. Again, this exploratory study suggests that interest often drives behaviors and how individuals interact with the object of interest.

Hulleman and Harackiewicz (2009) used a randomized field experiment investigating the level of motivation in high school science students. The results suggested that increasing the personal motivations of students through more relevant science tasks leads to more engagement and interest in the science classes. Hulleman and Harackiewicz point out that the situational interest developed as a result of tasks perceived as relevant by high school students leads to behaviors promoting higher achievement.

On the other hand, Meece, Blumenfield, and Hoyle (1988) found that fifth and sixth grade science students' levels of engagement depended upon their goals, motivation, and level of interest in science activities. Students with less intrinsic interest or motivation in science learning were less engaged in the science activities than those students that reported a higher level of interest and motivation in learning science. In this study, 275 fifth and sixth graders were first assessed on their goal orientations, motivation, and attitudes towards science. Subsequently, the students were observed during six science lessons to obtain information about their engagement patterns. At the conclusion of each lesson, students completed some form of assessment product such as a worksheet or report. What is most significant about these results is that students reporting a strong interest and motivation for learning science demonstrated a high level of engagement during the science activities. The levels of engagement were measured using a Likert-scale including items such as attention, planning, connecting concepts, and self-monitoring behaviors.

## Summary of Existing Research

The literature discussed here provides a framework for the three research questions posed in the previous chapter. As mentioned at the opening of this review, several assumptions are made about early exposure to formal science experiences, the nature of these early science experiences with regard to the allotment of time devoted to these experiences in the elementary school classroom. In addition, science achievement and engagement are the result of several factors over multiple years of formal science education and not the result of one single factor or year. Finally, there is a specific knowledge base and skill set that is nurtured only through elementary classroom science experiences and cannot be adequately developed outside of the classroom. The empirical studies presented in this review sought to justify such assumptions and provide ample justification for the research questions posed in this the previous chapter.

This review suggests that significant progress has been made in exploring the importance of early science learning on interest, achievement, and engagement in science learning. Likewise, the current body of research provides an overview of the frequency, duration, and avoidance of elementary science teaching. The focus of this study is to look at the pattern of growth associated with science achievement in terms of frequency, duration, and time devoted to science in the elementary school and its association with the level of student engagement in science.

In sum, the research indicates that early experiences are important in the development and progression of ideas about science and that young learners are developmentally primed for these experiences (e.g., Driver et al., 1994; Rahayu & Tytler, 1999; Fleer & Robbins, 2003b; Tytler & Peterson, 2003). In addition, interest in science develops early and is often linked to early experiences in school-based science experiences (e.g., Tai et al., 2006; Maltese & Tai, 2010;

Cleaves, 2005; Lindhal, 2007; Osborne, Simon, & Collins, 2003). This interest in science is often associated with achievement in science and later performance in science and science-related areas (e.g., Singh, Granville, & Dika, 2002; Good & Beckerman, 1978; Reynolds & Walberg, 1992). In the end, this interest translates into a set of positive and measurable behaviors that are an expression of this interest within the science classroom (e.g., Krapp, Hidi, & Renninger, 1992; Prenzel, 1992; Renninger, 1992).

Beyond early experiences and the development of early interest, demographic factors play a role in science achievement. The literature strongly suggests that the achievement gap between males and females, racial and ethnic groups, and low and high socioeconomic status cannot be attributed to ability but to equity and accessibility of early science experiences (e.g., Lee & Buxton, 2008; Spelke, 2005; Iverson & Walberg, 2002). The influence of gender, race, and socioeconomic status suggest cofounding variables that must be addressed to effectively investigate the proposed research questions.

Finally, the amount of time allocated for science instruction varies greatly from classroom to classroom and in many cases is minimal relative to other content areas such as reading, writing, and mathematics. One study found that science activities occupied 11% of the time in a fifth grade classroom. When compared to the 17% of time allotted to instructing students on managing materials and time, this figure is even more alarming (Pianta et al., 2007).

This expansive review of literature adequately justifies the proposed study in that it provides a complete rationale for asking questions about the trajectory of science achievement from the end of third grade to the end of eighth grade, the association of time allotted for science on this achievement, and finally, the association of student engagement in science by the time students reach the eighth grade, approximately age 13 or 14.

## Limitations of Existing Research

The existing research is not without limitations. First, many of the articles or studies presented here utilized small sample sizes, which limit the generalizability of the results. In many cases, the sample size consisted of a few students or a single class (e.g., Thomas, 1999; Tytler & Peterson, 2003; Ravanis & Bagakis, 1998). Studies like those conducted by Hadden and Johnstone (1982; 1983) looked at international student populations that have culturally unique experiences and are, again, limited in generalizability. Secondly, several of the studies did not look at longitudinal data (e.g., Stein & McRobbie, 1997; French 2004; Gelman & Brenneman, 2004). In these studies, only a snap shot of student achievement was investigated without looking at long-range outcomes across subsequent years. With the exception of Tai et al. (2006), the studies that did collect longitudinal date did so in the form of qualitative interviews and or observations. Although these studies contribute to the overall understanding of early experiences, interest, and achievement, the nature of these studies continues to limit the generalizability of results.

The specific variables used in the analyses are limiting as well. In studies such as those conducted by Cleaves (2005) and Hadden and Johnstone (1982; 1983), the variables used to measure science interest provided a limited view of the expression of interest by science students. In both of these studies, the science interest variable was based solely on course enrollment in the secondary school. This is problematic in light of the research on selective persistence and the wide array of behaviors associated with the manifestation of interest.

For those studies investigating the frequency, duration, and time devoted to science, the focus was often on single years of science and did not look at the impact of this lack of science time beyond that single year (e.g., Pianta et al., 2007; Rowan, Correnti, & Miller, 2002). In other words, the time allotted for science instruction was associated with immediate outcomes rather than long-range outcomes in both achievement and interest. In most cases, the frequency, duration and time devoted to science was simply measured without any attempt to study the association with specific outcomes. Studies looking at the avoidance of teaching science simply documented that it occurs but did not investigate the possible learning or achievement outcomes that may result from such avoidance of teaching science (e.g., Harlen, 1997).

The definition of time allotted varied between studies making a comparative analysis difficult. Studies defined time allotted to science instruction one three ways: (1) the amount of time devoted to homework (Betts, 1997); (2) number of hours spent in class (Figlio, 1999); or (3) number of semesters enrolled in science courses (Walberg et al., 1986). These methods of operationalizing time spent on science instruction are not particularly helpful in addressing the specific questions and assumptions associated with this study.

The most significant limitation of the existing research and a limitation that the proposed study is designed to address is the combination of achievement, time allotted for science, and level of engagement into one study. None of the studies in this review look at the pathway and pattern of science achievement across multiple years, how it is influenced by the amount of time devoted to science instruction, and how this influences later engagement in the science classroom. This study seeks to address the set of research questions mentioned at the beginning of this chapter that incorporates longitudinal achievement, the amount of time allotted for formal science instruction, and the manifestation of student interest in science.

# CHAPTER 3

# METHODOLOGY

The goal of this analysis is to address the following research questions using descriptive analyses, growth curve modeling, and structural equation modeling:

1. What is the pattern of growth for first-time kindergartners in science achievement from the end of third grade to the end of eighth grade?
2. Controlling for differences in student demographics, are gains that first-time kindergartners make in science achievement from the end of third grade to the end of eighth grade associated with the frequency, duration, and time devoted to science in the third grade?
3. Controlling for differences in student demographics is the frequency, duration, and time devoted to science in the third grade associated with the students' interest in eighth grade science?

What follows is an overview of the Early Childhood Longitudinal Study, Kindergarten Class of 1998-1999 (ECLS-K), a multisource, multi-method study sponsored by the United States Department of Education, Institute for Education Sciences, and the National Center for Education Statistics. The data analyzed in this study included a subset of the variables contained in the complete ECLS-K data set as well as a subsample of the cohort of students enrolled in kindergarten during the 1998-1999 school year or incorporated with the re-freshening of the sample a year later. The following overview of ECLS-K includes a description of the data collection instruments that were directly relevant to addressing the three research questions for this particular study. Although eight questionnaires, three achievement tests, and a physical measurement form were all used to collect this longitudinal data, only child level and teacher level data was included in this analysis. This chapter presents the analytic approach for answering the three research questions above as well as a careful discussion of the outcome variables, control variables, and predictor variables for each component of the analysis. Finally, a description of the study sample, the use of sample weights and weighting procedures, and the alternative algorithm for calculating variance in this study is provided.

## ECLS-K: Early Childhood Longitudinal Study, Kindergarten Class of 1998-1999

The ECLS-K is a longitudinal study that followed a national representative cohort of students from the time they were in kindergarten, the 1998-1999 school year, through the eighth grade or 2006-2007 school year. The purpose of ECLS-K study was to investigate children's early school experiences and what factors contribute to the children's progress through the elementary and middle school years. In total, 21,260 kindergarteners participated in the first data collection during the fall of 1998. Data collection occurred at subsequent times through the spring of the participants eighth grade year. Each spring collection included the full sample of participants along with the initial collection during the fall of 1998. However, to provide researchers the opportunity to look at trends over the summer months or the time between school years, thirty percent of the full sample was randomly selected and data was collected from this subsample in the fall of their first grade year.

The first wave of data collection, the fall of 1998 kindergarteners were selected based on primary sampling units using a multistage probability design. In the interest of cost and study efficiency, primary sampling units were composed of counties or groups of counties. The measure of a primary sampling unit size was based upon the number of five year olds contained within the primary sampling unit. However, Asian and Pacific Islanders were oversampled. 100 primary sampling units were randomly selected. Public and private schools offering kindergarten within the primary sampling units were then randomly selected. Finally, children were random selected from the pool of public and private schools offering kindergarten. This is a multistage probability design. The second wave of data was collected in the spring of 1999.

The third wave of data collection occurred during the fall of 1999 from a subsample of the original sample. The fall of first grade wave of data collection was designed to allow researchers to look at the influences of the summer months on learning. This subsample was comprised of a 30% random sampling of the full sample. The fourth wave of data collection occurred during the spring of first grade and included the full sample plus freshening. In other words, students not enrolled in kindergarten in 1998-1999 but were enrolled in the first grade during the 1999-2000 school year were included into the study. This freshening of student implies that the selection of students added to the study followed the same multistage probability design as the original base year sample.

Subsequent waves of data collection occurred for the full sample during the spring of students' third grade year, fifth grade year, and finally, eighth grade year. In total, the ECLS-K study includes seven rounds of data collection (see Table 3-1). One notable feature of the ECLS-K data set is in regard to national representations. The base year or first wave of data collection is nationally representative of all kindergarteners in the United States during the 1998-1999 school year. However, due to attrition, subsequent rounds are representative of the population cohort rather than all students. For example, the fifth grade wave of data collection is representative of the original cohort but not all fifth graders in the United States during the 2003-2004 school year.

The data collected for the ECLS-K study comes from multiple sources across multiple methods including direct child assessments; student records abstracts, parent, teacher, and administrator interviews. During the 2006-2007 data collection year, the eighth grade participants also completed a student questionnaire about their school experiences, self-perceptions, and physical fitness and health characteristics. A summary of the specific data collected for each wave is provided in Table 3-2. The design of this longitudinal study and the decision to incorporate data from children, parents, teachers, and administrators is based on a conceptual model that recognizes multiple factors from the child's environment at school, home, or in the community contribute to the progress of that child through formal schooling from kindergarten to the eighth grade. Thus, school outcomes, whether elementary or middle school outcomes, are associated with a vast collection of interconnected factors (Tourangeau, Nord, Le, Sorongon, & Najarian, 2009).

This analysis utilized child level data from the spring of third grade, spring of fifth grade, and spring of eighth grade to address the research questions presented at the beginning of this chapter. The decision to focus on this particular segment of the longitudinal data as well as the particular sequence of third, fifth, and eighth grade is a direct result of the research questions and what data was needed to address them. What follows is a discussion of the analytical approach and the variables that were necessary for the analysis. Most notably, science achievement scores were collected during the spring of third grade, spring of fifth grade, and spring of eighth grade years. This data was not available, independently, during the kindergarten or first grade waves. Thus, a longitudinal analysis of science achievement was possible for only the last three waves of data collection.

## Analytical Approach

The analytic approach for addressing the research questions proposed in this study included descriptive analyses, growth curve modeling, and linear modeling. What follows is a description of the analytic approach carried out to answer the research questions. A more detailed discussion and description of the outcome, control, and predictor variables listed in this analytic plan occurs in a separate section of this chapter.

Descriptive analyses were run to provide information on sample demographics as well as measures of central tendency for outcome, control, and predictor variables.

### *Growth Curve Modeling*

The research questions proposed in this study seek to describe the pattern of growth for first-time kindergartners in science achievement from the end of third grade to the end of eighth grade, investigate how this growth is related to time devoted to science in the third grade, and finally, how this is associated with science interest in the eighth grade. Given that the intent of the first two research questions presented in this study is not only to describe the change in science achievement over time, but also investigate how that change is related to the duration, frequency and time devoted to science in the third grade, the most suitable analytic method for addressing these questions one and two was growth curve modeling (Fan & Konold, 2009). Growth curve modeling provides information about how people, in this case children participating in the ECLS-K study, change with regard to a dependent variable across multiple measurements in time. This analysis focused on the change over time (i.e., from spring of third grade to spring of eighth grade) in science achievement using three assessment time periods. The reason for selecting growth curve analysis over other analytic procedures was the nature of the research questions proposed in this study.

Traditional repeated measures procedures such as ANOVA or MANOVA address the means of the group and assume that all members of the group can be described by the same profile with any individual variations being attributed to error (Weinfurt, 2000). On the other hand, growth curve analysis using structural equation modeling (SEM) provides the opportunity to make inferences about the rate of change or growth and an outcome variable such as science achievement. For example, what factors are associated with the nature of the change of growth in the outcome variable? Traditional methods such as ANOVA or MANOVA do not allow for such inferences nor provide as much statistical power for detecting group differences in potentially linear growth trajectory parameters (Fan, 2003). In addition, the use of SEM provides statistical information about the appropriateness of the proposed growth model that is not provided when growth curve analysis is performed using hierarchical linear modeling (HLM). Put differently, the use of SEM provides more statistical power and information about how well the overall model fits the data as well as specific parameters within the model. The use of SEM in this analytic approach provided the most comprehensive look at the proposed research questions.

To address the first research question, an unconditional growth model was developed in AMOS® 18 using science assessment scores from spring of third grade, spring of fifth grade, and spring of eighth grade. The ECLS-K study only assessed science independently during the last three waves of data collection. Prior to spring of third grade, science and social studies were assessed together in a general knowledge, direct cognitive assessment. The unconditional growth model is presented in Figure 3-1. The unconditional model represents the growth trajectory of science achievement without any predictors or covariates. The model fit statistics (e.g., $\chi^2$, root-mean-square error of approximation, normed fit index, and comparative fit index) were assessed to determine the overall model fit. Similarly, the growth trajectory estimates (i.e., the slope and intercept of the growth curve) were evaluated to determine if statistically significant individual variation exists around the starting point and growth rate associated with science achievement. The unconditional model was adjusted to determine if the growth curve follows a linear, quadratic, or spline pattern by altering the time increments placed in the model. From these three growth pattern analyses, a decision was made using the statistical parameters about which growth pattern best describes science achievement from spring of third grade to spring of eighth grade.

After a suitable growth pattern was selected (i.e., linear, quadratic, or spline), the predictor variables frequency and duration of time devoted to science instruction in the third grade were added to the model. This addressed the second research question proposed in this study. The second question seeks to understand if the two predictors mentioned previously can account for individual variations in the intercept and slope of the growth trajectories associated with science achievement. This conditional growth model, also constructed in AMOS® 18, is presented in Figure 3-2. As discussed with the unconditional model, the model was evaluated for overall fit as well as to see if the predictors significantly reduced the amount of individual variation in the growth trajectory of science achievement. This model included the control variables gender, race, ethnicity, socioeconomic status, and disability status.

*A Linear Model of Interest and Engagement*

To address the third research, a third linear model, presented in Figure 3-3, was constructed in AMOS® 18 with the frequency and duration of time devoted to science in third grade as the independent variable and science interest in the eighth grade as measured by the eighth grade academic rating scale for science as the dependent variable. The use of a structural equation model approach to analyze question three when this question could easily have been addressed using basic linear regression was a matter of convention and consistency.

First, the structural equation modeling subsumes linear regression and thus is both an acceptable and appropriate means for evaluating models like the one proposed in question three (Bentler, 1992; Fan 1996; Joreskog & Sorbom, 2001; Thompson, 2000). Secondly, the use of structural equation modeling allowed for the same statistical software package to be used throughout the entire study. In turn, the handling of missing data, the application of weights, and the calculation of variances were consistent.

As with the growth curve models, the control variables gender, race, ethnicity, socioeconomic status, and disability status were included in this third structural equation model.

What follows is a thorough discussion of the outcome, control, and predictor variables utilized in the analytic approach.

## Outcome Variables

### *Direct Cognitive Assessment for Science*

The direct cognitive assessments administered with ECLS-K are comprised of a battery of assessments including a general knowledge assessment for the kindergarten and first grade waves, a reading assessment for all waves, and a mathematics assessment for all waves. The general knowledge assessment administered during the kindergarten and first grade waves of ECLS-K included topics from the natural sciences as well as the social sciences. Starting with the third grade collection, a separate science assessment was developed and administered during the spring of third grade, spring of fifth grade, and spring of eighth grade. Thus, studies involving gains in science can only span across those years.

The direct cognitive assessments generated two types of scores for each battery administered, IRT based scores and non-IRT based scores. IRT based scores included calculations such as scale scores, T-scores, and proficiency probability scores. Non-IRT based scores included number right or raw scores and print familiarity or decoding text scores. Given that the focus of this analysis will be on achievement across time, the use of IRT scale scores was most appropriate.

IRT scale scores in the ECLS-K data set represent estimates about the number of questions the child would have answered correctly if he or she had answered all items. Using the pattern of right, wrong, and omitted responses, the child is more accurately placed on a continuum of ability. In addition, IRT uses difficulty and guess-ability to better assess the child's cognitive ability within the focus area of the assessment.

*Science IRT Scale Scores*

The ECLS-K data contains science IRT scale scores for spring of third grade, spring of fifth grade, and spring of eighth grade. As mentioned previously, IRT scale scores represent children's performance on the entire assessment. The science assessment places equal emphasis on life, physical, earth, and space science. The child must demonstrate his or her ability in both content and processes associated with science such as drawing inferences, comprehending relationships, interpreting scientific data, formulating hypotheses, and developing a plan for addressing a scientific question. Thus, a single Science IRT Scale Score represents each child's breadth and depth of science knowledge and understanding. For this analysis, the Science IRT Scale Scores are identified as C5SR2SSCL, C6SR2SSCL, and C7SR2SSCL for the spring of third grade, spring of fifth grade, and spring of eighth grade, respectively. These IRT scale scores were first be used to describe the pattern of growth for first-time kindergartners in science achievement from the end of third grade to the end of eighth grade.

*Academic Rating Scale*

The Academic Rating Scales (ARS) are part of the indirect cognitive assessments used in ECLS-K data collection. Indirect cognitive assessments are those assessments that were collected about the child rather than from the child (i.e., Direct Cognitive Assessments).

Specifically, teachers were asked to rate each child on his or her abilities and performance in the classroom. For example, science teachers were asked to rate the student's ability in organizing data, solving science problems, designing experiments, and talking or presenting about science. Other questions addressed the specific behaviors of the student while in science class. The behaviors included the number of times the student was tardy, how attentive he or she was while in class, how well the student engaged in activities, and the general disposition of the student towards the science class. Specific examples of questions from the Academic Rating Scale for Science are provided in Figures 3-4 through 3-7.

*Science Interest Variable*

The science interest variable for this study was the student's ARS score from the eighth grade science teacher questionnaire. The use of the ARS for science as the interest variable comes from the body of literature linking student interest with a set of behaviors such as persistence, focus, and engagement in a specific area (Hidi, 2006; Deci, 1992; Penzel, 1992; Renninger & Wozniak, 1985; Allport & Vernon, 1981). The types of questions found on the science ARS questionnaire are in line with the behaviors observed in students interested in science tasks (Good, 1983; Good & Beckerman, 1978; Young, Reynolds, & Walberg, 1996). Therefore, this study operationalized interest in science in the eighth grade by using the ARS science scores.

The ARS score was calculated using all responses provided by the teacher and converting the score to a scale score ranging from one to five where one indicates that the child has not yet demonstrated the necessary skills, knowledge, or behaviors in science and five indicates that child competently and consistently demonstrates the necessary skills, knowledge, and behaviors in science. The ARS score for eighth grade science (T7ARSSCI) served as an outcome variable and addressed the third and final research question proposed in this study: is the frequency, duration, and time devoted to science in the third grade associated with the students' interest in eighth grade science?

## Control Variables

### *Composite Variables*

To assist in the analysis of the ECLS-K survey data, the data file contains several composite variables. Composite variables are new variables based on data from multiple existing variables often collected from multiple sources. The use of composite variables provides two immediate benefits to an analysis. First, the difference availability of some data between restricted access data and public-use data makes certain single data unavailable to most analyses. By developing a composite variable, the restricted access data is anonymously calculated into the newly formed composite variable. Second, these variables are updated in subsequent rounds and provide the most accurate information associated with the composite variable.

Composite variables serve as a more comprehensive source of information about certain child characteristics such as race and ethnicity, socioeconomic status, and disability status. For example, socioeconomic status is a composite variable composed of multiple indicators rather than a single question or measure commonly found with other socioeconomic status variables. This analysis utilized four control variables that are also composite variables in the ECLS-K data set: gender, race and ethnicity, socioeconomic status, and student disability status.

### *Gender*

Literature surrounding gender in science learning and achievement indicates a potential gender difference (i.e., Brotman & Moore, 2008; Scantlebury & Baker, 2007; Bleeker & Jacobs, 2004). In some studies, the gender difference is attributed to differences in gender equity in and access to science experiences (Spelke, 2005; Andre, Whigham, Hendrickson, & Chambers, 1999; Baker, 1998). For these reasons, gender was controlled for in this analysis with the gender composite variable.

The gender composite variable, R7GENDER, was calculated from subsequent years and multiple sources. In other words, to develop this particular composite variable, the reported gender from the student's kindergarten, first grade, third grade, and fifth grade data was compared with the gender indicated in the parent interview, and child reports. If the reported or indicated gender of the child differed at any point, several secondary procedures were used to develop the composite variable. For example, the most frequently reported gender was used in the calculation of R7GENDER. If both genders were reported equally, the source of the data was then used to determine the variable (i.e., parent reported data over child reported data).

Gender was dummy coded in this analysis with males as the comparison group. Males were recoded with a value of zero while females were recoded with a value of one. Syntax for this recoding is provided in Appendix A.

*Race and Ethnicity*

The achievement gap between different races and ethnic groups appears early and continues through the educational paths of minority students (Lee & Buxton, 2008; Buck, Cook, Quigley, Eastwood, & Lucas, 2009). Although studies report that a culturally responsive curriculum begins to close the achievement gap (Aikenhead, 2001; Matthews & Smith, 1994), other studies indicate that the gap continues to widen in spite of these culturally responsive curricula (Lee & Buxton, 2008). Thus, controlling for race and ethnicity is essential in this analysis. Race and ethnicity was controlled for using the composite variable W8RACETH.

The race and ethnicity composite variable, W8RACETH, was developed using six dichotomous race variables and a Hispanic ethnicity variable. This information was obtained from parent interviews only. If parent interview data was available in earlier collection waves but missing in later waves, previous race and ethnicity responses were copied and carried forward. Furthermore, if only ethnicity was reported, the composite variable was calculated with only ethnicity included.

The W8RACETH variable was also dummy coded for this analysis. For each of the categories represented (i.e., White, Black, Asian, Hispanic, Pacific Islander, Native American, No Response, and Multiple Categories) a dummy variable was created with children reporting their race as white acting as the comparison group. The syntax utilized for this recoding is found in Appendix A.

*Socioeconomic Status*

The availability of resources and support that is often not as plentiful for students of lower socioeconomic status appears to influence science learning and achievement (Iverson & Walberg, 2002; Xin, Xu, & Tatsuoka, 2004; Knapp & Plecki, 2001; Chapin, 2007; Judge, Puck, & Bell, 2006). The literature investigating the influences of socioeconomic status varies in their attribution of why this influence exists. What appears to be obvious is that how socioeconomic status influences science learning and achievement is not attributable to a single source (Iverson & Walberg, 2002; Judge, Puck, & Bell, 2006). Controlling for this component in any analysis is challenging in that the indicators of socioeconomic status vary as well (i.e., parental education, parental occupation, household income). For this specific analysis, the composite variable W8SESQ5 was used to control for socioeconomic status.

The composite variable W8SESQ5 provided a significant benefit to this analysis in that the calculation of this variable comes from multiple indicators of socioeconomic status rather than a single indicator (e.g., only using parental education) common in other analyses. The calculation of this variable was based on five indicators and multiple scales associated with those indicators. These five indicators were: male parental/guardian education, female parental/guardian education, male parental/guardian occupation, female parental/guardian occupation, and household income. In addition to these indicators, the 1989 General Society Survey prestige score informed occupation component of this composite variable. The issue of missing data for this particular variable is a significantly more challenging issue to address. In the case of missing data, hot-deck imputation was used to account for missing data if the information was not available in previous data collection waves less than three years old. In other words, if the last reported set of indicators was more than three years back, imputation was used.

For this analysis, the W8SESQ5 variable was recoded into low, medium, and high socioeconomic status. In the original data set, the W8SESQ5 variable was divided into quintiles. As recommended by the NCES, this variable was recoded so that the first quintile was recoded to one, representing “low SES”, the second, third, and fourth quintiles were recoded to tow, representing “middle SES”, and the fifth quintile was recoded to three, representing “high SES" (Tourangeau et al., 2009). The syntax utilized for the recoding of this variable is presented in Appendix A.

*Student Disability Status*

Although the association between a student’s disability status and science learning and achievement was not discussed explicitly in the review of literature, the influence of student disabilities on general achievement is common throughout special education research. By definition, learning disabilities are identified based on the gap between a student’s potential and his or her actual achievement. Thus, the assumption that a student’s disability status is associated with achievement is both supported and well established in the literature (Lerner & Kline, 2006). The emphasis on students with disabilities is above and beyond the scope of this particular study, the failure to control for this factor would potentially limit the interpretation and implications of any results. Therefore, students' disability status was controlled for using a composite variable, P7DISABL.

The composite variable for a particular student's disability status was based on parent interviews about specific behaviors such as anxiety, depression, or emotional behaviors along with difficulties hearing, seeing, and or communication. Depending on the responses to the previous characteristics, parents were asked if any of these behaviors or difficulties resulted in the diagnosis from a professional. Finally, the parent interviews included questions about the intervention of a therapist or participation in programs for children with disabilities. This composite variable encompasses a wider range of disabilities then the traditional measure of a student having an Individualized Education Plan or IEP.

In this analysis, the P7DISABL composite variable was dummy coded. The number zero represented those students with no reported disability while the number one represented those students with a reported disability. The syntax utilized for the recoding of this variable is presented in Appendix A.

## Predictor Variables

The predictor variables for this analysis were the frequency, duration, and time devoted to science in the third grade. The body of literature investigating the nature and influence of the time allotment devoted to science instruction in the elementary school (Good, 1983; Pianta, Belsky, Houts, & Morrison, 2007; Goodrum, Hackling, & Rennie, 2001; Osborne & Simon, 1996; Harlen, 1997) provides strong support for the analytic model in this study. Each of the studies mentioned above and more thoroughly in the previous chapter suggests that a minimal amount of time is set aside for science instruction (Good, 1983; Pianta, Belsky, Houts, & Morrison, 2007). In addition to this diminishing science instructional time, Harlen (1997) points out that teachers are actually avoiding science teaching for a variety of reasons beyond just simply running out of time during the day. Combining the time devoted to science literature with the research on early experiences (Driver et al., 1994; Fleer & Robbins, 2003b) and early interest in science (Tai et al, 2006; Maltese & Tai, 2010), this diminished allotment or absence of science instruction may strongly influence later science achievement and interest. Although it appears no study has directly addressed this issue, qualitative data from studies like Maltese and Tai (2010), Stein and McRobbie (1997), and Rahayu and Tytler (1999) suggest that the science education of students is dependent upon early exposure to science.

Thus, the predictor variable for this analysis was the time devoted to science (frequency and duration) in the third grade. These variables (A5OFTSCI and A5TXSCI) are from the teacher questionnaire associated with the third grade year. The exact question on the third grade, teacher questionnaire is presented in Figure 3-8. With regard to the specific wording of the question in Figure 3-8, the possibility exists for different interpretations of how to appropriately answer the question. For example, teachers may respond to the second part of the question, “how much time” as an extension of the first part of the question or as an independent question. In other words, if a teacher responds that he or she offers science instruction “1-2 times a week”, does the second question as about the amount of time spend during those “1-2 times a week” or as a separate and independent question? To avoid interpretation issues on all direct and indirect assessments, the NCES placed representatives in each school and classroom to address any questions that arose during the data collection process. This provided a realistic counter-measure for the methodological issue of interpreting survey questions for each wave of data collection.

## Missing Values

As with any large-scale survey study, the issue of missing data must be addressed. The analytic procedures described earlier in this chapter utilized statistical software packages that have built-in algorithms for handling missing data (i.e., AMOS® 18). In this case, the analyses did not need additional missing data procedures.

## Sample

The children included in this analysis are a subsample of the 21,260 nationally representative kindergarteners that were enrolled in kindergarten during the 1998-1999 school year. This goal of this study was to investigate the science achievement of first time kindergartners through the spring of their eighth grade year. Therefore, the subsample of this population included children that were in the eighth grade during the 2006-2007 school year and were first time kindergarteners in 1998-1999. This study did not seek to address issue related to retaining students and thus did not include students who had repeated kindergarten and/or were not in the eighth grade during the 2006-2007 school year. Similarly, this study to focused on public science achievement and did not include students who reported attending private schools at any time during the ECLS-K study.

This subset of eighth graders is representative of the population cohort rather than all eighth graders in 2006-2007. Descriptive analyses (i.e., gender demographics and race and ethnicity percentages) were conducted on the sample for this study to ensure that it remained representative of the population cohort.

## Weights

To indicate the relative strength of an observation, weights are applied to observations within data sets. In the most basic data set, each observation is counted equally, that is, each observation represents the same number of cases. For example, a simple random sample implies that every object or participant had an equal probability of being included in the study. In the ECLS-K data set, different cases or children have different probabilities of being selected due to the complex sampling of the population. Children are clustered within primary sampling units to reduce the costs of collecting data in the field. Primary sampling units, in this case, were counties or group of counties selected with probability proportional to size. The primary sampling units were then randomly sampled, followed by randomly sampled schools within the primary sampling units, and then children were randomly sampled within the schools. The measure of size was the number of five year olds within the primary sampling unit. Also worth noting, Asian and Pacific Islanders were oversampled. Therefore, the ECLS-K data is a complex sample and any appropriate analysis using this data should also use weights.

The ECLS-K weights allow statements to be made about the population of either children in kindergarten during the 1998-1999 school year or children in the first grade during the 1999-2000 school year. These weights count each case relative to its representation in the population, adjust for differential selection probabilities, and reduce bias associated with non-responses. In addition, the particular weight necessary for analyses will depend on three factors: first, what level of analysis is being done (i.e., child, teacher, or school level data), second, whether the analysis is a cross-sectional analysis or a longitudinal analysis, and third, the source of the data (i.e., child assessment, parent interview, teacher questionnaire, or student questionnaire).

The analyses associated with research questions one and two in this study used child level data, was longitudinal in nature, and from child assessments and teacher questionnaires. The recommended weight for these analyses and consequently the one applied to the analyses was C567CWO. The Combined User's Manual for the data recommends this weight for analyses that use direct child assessment data from three rounds of data collection (i.e., spring of third grade year, spring of fifth grade year, and spring of eighth grade year), child characteristics, and data from any round of teacher questionnaires (Tourangeau et al., 2009).

The analysis associated with the third and final research question also used child level data from child assessments and teacher questionnaires, but was cross-sectional in nature. In addition, the third research question relied upon data from the science teacher questionnaire. A subsample of the original ECLS-K cohort was selected to receive a science teacher questionnaire. Thus, the weight utilized in this third and final analysis must adjust for this additional selection criterion. The recommended weight and the one applied to this analysis was C7CPTSO. The Combined User's Manual for the data recommends this weight for single year, cross-sectional analyses that draw from child level data and include those students with data from the science teacher questionnaire.

The detailed syntax associated with each of the two weights and their corresponding replicate weights is provided in Appendix A.

## Calculation of Variance

The most commonly used algorithms for calculating standard errors assume a simple random sample. These algorithms are utilized by most statistical software packages (e.g., SPSS). Given that the standard error indicates the level of precision associated with the estimates in an analysis, all confidence intervals and hypothesis testing procedures are based on the calculation of standard errors for a particular sample estimate. The sample design of the ECLS-K data set does not met this assumption of a simple random sample. The complex nature of the ECLS-K sample is due to two methodological decisions made in the study design. First, children are clustered within primary sampling units to reduce the costs of collecting data in the field. Again, primary sampling units were counties or group of counties selected with probability proportional to size. The measure of size was the number of five year olds within the primary sampling unit. As mentioned earlier, Asian and Pacific Islanders were oversampled. Second, the use of primary sampling units meant that children were selected in closer geographical proximity than would usually occur in a simple random sample. Likewise, children selected within a primary sampling unit are more similar to one another across multiple characteristics than the same number of children selected in a simple random sample (Tourangeau et al., 2009).

The violation of a simple random sample in the calculation of variance results in underestimating the standard errors of estimates from complex samples. In other words, the data from complex samples tend to be less variable than a simple random sample. The inaccurate calculation of standard error frequently leads to Type I and Type II errors or a failure to detect a significant finding or the detection of a statistically significant finding when one does not exist (Cochran, 1977; Lee, Forthofer, & Lorimor, 1989).

To account for the complex samples in this specific study, an alternative method was implemented to make precise adjustments necessary to calculate standard errors or variance of the estimates. The use of primary sampling units, or PSUs, creates a cluster-sampling design and thus effects the calculation of standard errors. This cluster-sampling effect is commonly referred to as a design effect in the literature (Kish, 1965; NCES, 2002). Specifically, the equation presented in Figure 3-9 incorporated cluster size and the intraclass correlation coefficient to provide a more accurate value for standard errors or variances of the estimates (Kerry & Bland, 1998). The estimation of the design effect from this equation is based on the ratio of the design effect standard error to the standard error calculation ignoring the design effect. Although a detailed discussion of the derivation of this correction factor is not necessary for this study, what is valuable is a general discussion of the conceptual idea of the design effect along with the specific formula applied to the analytic procedures utilized in this study.

The design effect or DEFT for the three waves of data collection utilized in this study are 1.84 for the third grade wave, 2.04 for the fifth grade wave, and 1.83 for the eighth grade wave. To appropriately correct for the complex design, the average of these three DEFT values (1.90) was multiplied by each of the standard errors generated by the AMOS® 18 program that assumed a simple random sample in both the unconditional and conditional growth models. From this correction, a new critical ratio or test statistic was calculated and an adjusted *p* value was generated.

To application of the DEFT for the linear regression model followed a different procedure. Using AMOS® 18 to model linear regression produces a saturated model with no degrees of freedom. Thus, the design effect of 1.90 was multiplied by the standard errors generated and new critical ratio was calculated as in the two previous models. However, instead of a *t* statistic, a *z* score was generated and then an adjusted *p* value calculated.

**Table 3-1**

***Summary of Data Collected During Each Wave of ECLS-K***

| Wave or Round | Data Collection | Date of Collection | Population |
|---|---|---|---|
| 1 | Fall of Kindergarten | 1998 | Full Sample |
| 2 | Spring of Kindergaren | 1999 | Full Sample |
| 3 | Fall of First Grade | 1999 | 30% of Full Sample |
| 4 | Spring of First Grade | 2000 | Full Sample, Freshened |
| 5 | Sping of Third Grade | 2002 | Full Sample |
| 6 | Sping of Fifth Grade | 2004 | Full Sample |
| 7 | Spring of Eighth Grade | 2007 | Full Sample |

**SOURCE: Adapted from Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

**Table 3-2**

***Summary of Data Collected During Each Wave of ECLS-K***

| Data Collection | Data Collected | Direct Child Assessment Details |
|---|---|---|
| Fall of Kindergarten | Direct Child Assessments, Parent Interview, Teacher Questionaire | Child assessments for general knowledge only. |
| Spring of Kindergaren | Same as Fall of Kindergarten plus School Questionaire | Child assessments for general knowledge only. |
| Fall of First Grade | Direct Child Assessments, Parent Interview | Child assessments for general knowledge only. |
| Spring of First Grade | Direct Child Assessments, Parent Interview, Teacher and School Questionaires | Child assessments for general knowledge only. |
| Sping of Third Grade | Direct Child Assessments, Parent Interview, Teacher and School Questionaires | Includes separate assessments for science, mathematics, and reading. |
| Sping of Fifth Grade | Direct Child Assessments, Parent Interview, Teacher and School Questionaires | Includes separate assessments for science, mathematics, and reading. |
| Spring of Eighth Grade | Direct Child Assessments, Parent Interview, Teacher and School Questionaires | Includes separate assessments for science, mathematics, and reading. |

**SOURCE: Adapted from Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

***Figure 3-1. Unconditional SEM Growth Curve Analysis Model***

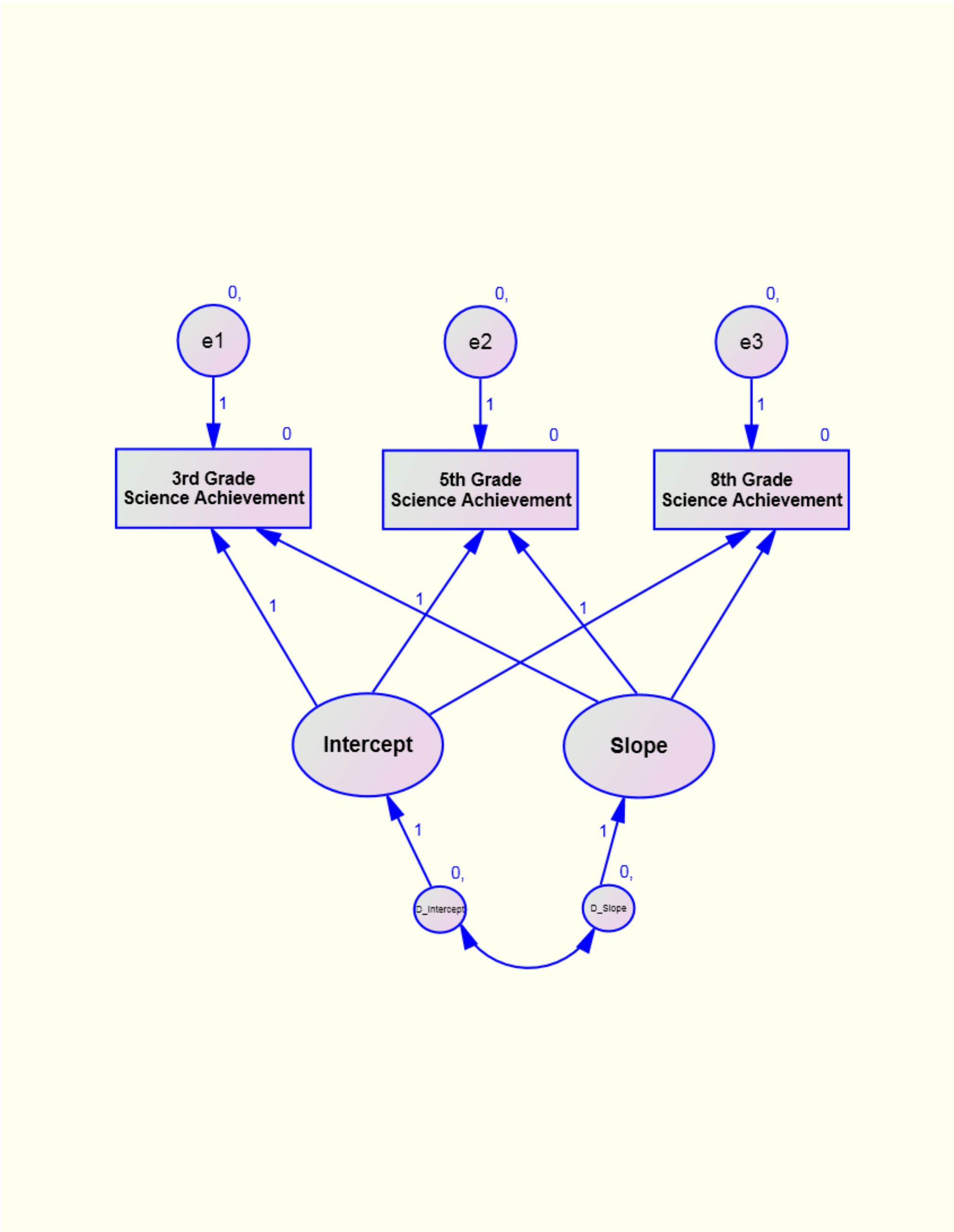


*Figure 3-2. Conditional SEM Growth Curve Analysis Model with Predictor Variables and Control Variables*

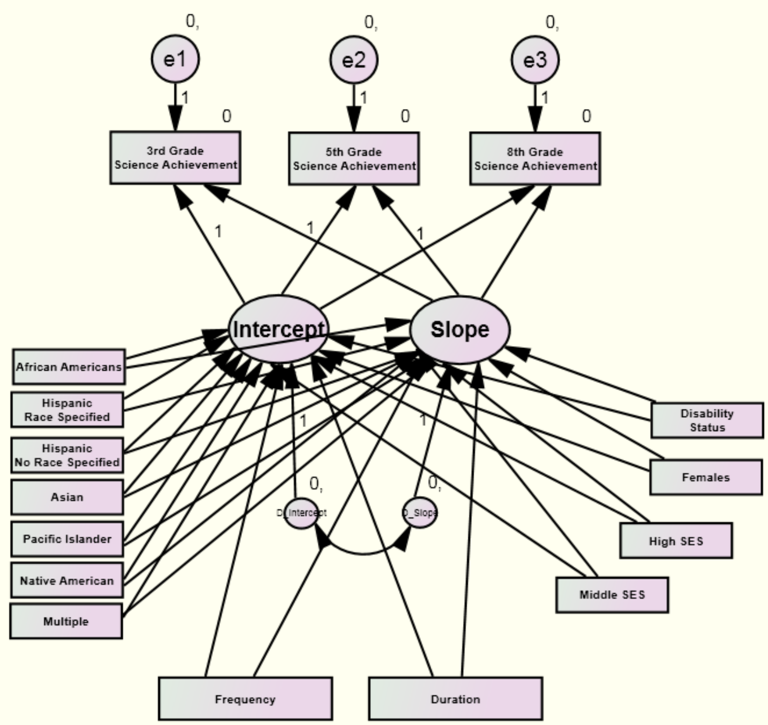


***Figure 3-3. Linear Time Allotted and Interest Analysis Model***

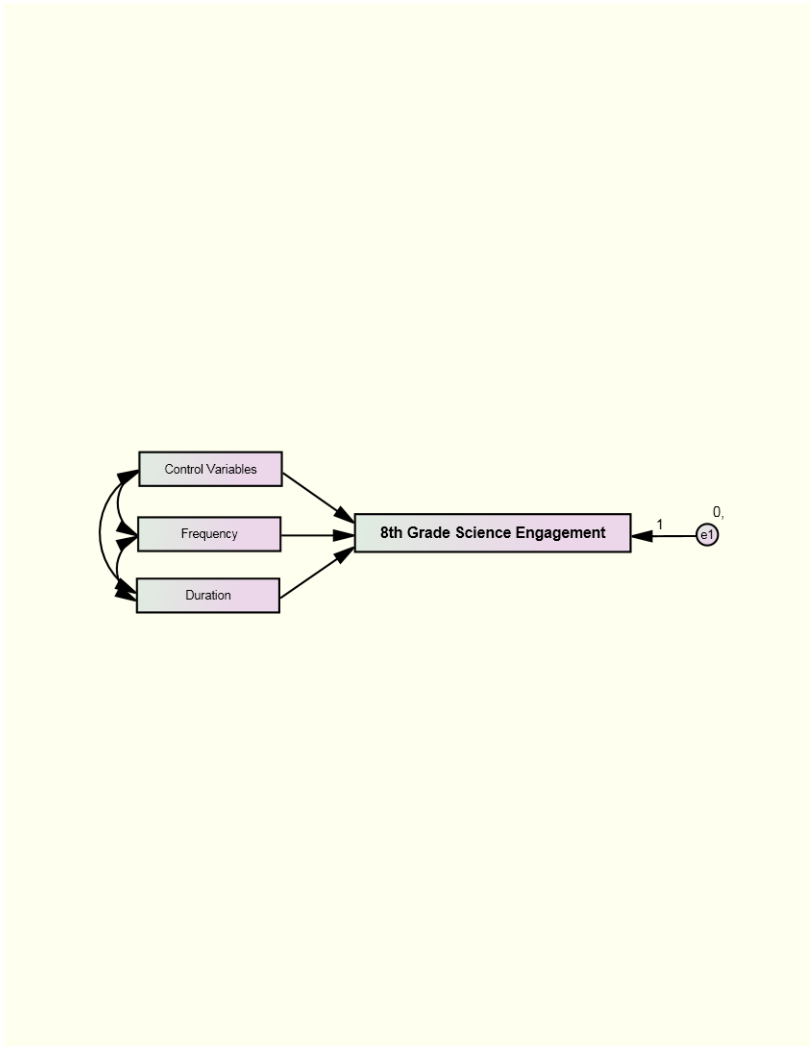


*Figure 3-4. Question #1 from Eighth Grade Science Teacher Questionnaire*

**1. Does this student usually work hard for good grades in your class?**

☐ Yes

☐ No

**SOURCE: from "Spring 2007 Grade 8 Science Teacher Questionnaire," by Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004), p.4. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

***Figure 3-5. Question #7 from Eighth Grade Science Teacher Questionnaire***

**7. When you assign homework for this class, how often does this student complete it? MARK ONE RESPONSE ONLY.**

- ☐ Homework not assigned
- ☐ Never
- ☐ Rarely
- ☐ Some of the time
- ☐ Most of the time
- ☐ All of the time

**SOURCE: from "Spring 2007 Grade 8 Science Teacher Questionnaire," by Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004), p.5. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

*Figure 3-6. Question #8 from Eighth Grade Science Teacher Questionnaire*

**8. How often is this student…**
**MARK ONE ON EACH ROW.**

| | Never | Rarely | Some of the time | Most of the time | All of the time |
|---|---|---|---|---|---|
| a. Attentive in your class? | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Disruptive in your class? | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. Absent from your class? | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. Tardy to your class? | ☐ | ☐ | ☐ | ☐ | ☐ |

**SOURCE: from "Spring 2007 Grade 8 Science Teacher Questionnaire," by Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004), p.5. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

*Figure 3-7. Question #11 from Eighth Grade Science Teacher Questionnaire*

**11. Please rate this student's skills in the following areas, as exhibited in your class. MARK ONE ON EACH ROW.**

| | Outstanding | Very good | Good | Fair | Poor | Not applicable/ not observed |
|---|---|---|---|---|---|---|
| a. Ability to organize data in tables or charts | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Ability to write up results or prepare a presentation from a laboratory activity, investigation, experiment or a research project | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. Ability to talk about ways to solve science problems, such as investigations | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. Ability to make a presentation to the class on science data, analysis, or interpretation | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| e. Ability to design his/her own investigation or experiment to solve a scientific question | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| f. Ability to apply science concepts to "real world" problems | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**SOURCE: from "Spring 2007 Grade 8 Science Teacher Questionnaire," by Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004), p.6. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

***Figure 3-8. Question Addressing the Frequency, Duration, and Time Devoted to Science Instruction in Third Grade from the ECLS-K Teacher Questionnaire for Wave 5***

26. **How often** and **how much time** do children in your class usually work on lessons or projects in the following general topic areas, whether as a whole class, in small groups, or in individualized arrangements? CIRCLE ONE NUMBER IN PART 1 OF EACH LINE. IF APPLICABLE, ALSO CIRCLE ONE NUMBER IN PART 2 OF EACH LINE.

| | **1. How Often** | | | | | **2. How Much Time** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Never** | **Less than once a week** | **1-2 times a week** | **3-4 times a week** | **Daily** | **1-30 minutes a day** | **31-60 minutes a day** | **61-90 minutes a day** | **More than 90 minutes a day** |
| a. Reading and language arts ...... | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| b. Mathematics........ | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| c. Social studies...... | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| d. Science ............... | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| e. Music.................. | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| f. Art........................ | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| g. Dance/creative movement ........... | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| h. Theater / creative dramatics ............ | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| i. Foreign language ............. | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| j. English-as-a-second-language (ESL)... | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| k. Reference skills (e.g., searching for information in books, on the computer/ Internet)............... | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |

**SOURCE: from "Spring 2002 Teacher Questionnaire Part A," by Tourangeau, K., Nord, C., Le, T., Sorongon, A. G., & Najarian, M. (2009). *Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), Combined User's Manual for the ECLS-K Eighth-Grade and K-8 Full Sample Data Files and Electronic Codebooks* (NCES 2009-004), p.9. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.**

***Figure 3-9. Equation for Calculation of Standard Errors or Variance of the Estimates***

$$DEFT = \sqrt{1 + (n-1)\rho}$$

**SOURCE: Kerry, S. M., & Bland, J. M. (1998). The intra-cluster correlation coefficient in cluster randomization.**
***British Medical Jounral, 316, 1455.***

# CHAPTER 4

# RESULTS AND CONCLUSIONS

This proceeding analysis is separated into three main components: (1) a description of the demographics for the study sample, science achievement, frequency, duration, and time devoted to science, and levels of science interest; (2) an analysis of students' growth pattern in science achievement from spring of third grade to spring of eighth grade and the association of this growth with the frequency, duration, and time devoted to elementary science instruction in third grade; and (3) an analysis of the association between the time allotted to elementary science instruction in third grade and science interest in the spring of eighth grade.

## Descriptive Analysis

The sample analyzed in this study was a subset of the 21,260 children enrolled in kindergarten during the 1998-1999 school year that were selected for inclusion in the ECLS-K study original cohort. This subset also included those children enrolled in first grade during the 1999-2000 school year that were added as part of the freshening of the original Kindergarten cohort. To appropriately and effectively address the specific questions proposed in this study, three specific selection criteria were applied to the ECLS-K population: children that were first-time kindergarteners, children enrolled in eighth grade during the 2006-2007 school year, and those children that attended only public schools from Kindergarten to eighth grade. The application of the above selection criteria sought to eliminate confounding factors that were beyond the focus of this study such as the association of grade retention, acceleration or skipping of grades, and private schooling on achievement and interest in science. As a result, the sample size for this study was 5,854. What follows is the descriptive analysis of the sample population across demographic variables controlled for in the study as well as the predictor and outcome variables utilized in the study. The purpose of including descriptive analyses was to provide an initial overview of the nature of the variables included in this study (i.e., distribution of the data and trends within certain variables). As a final note and emphasis, the reporting descriptive statistics for variables such as science achievement are not for the purpose of drawing inferential conclusions and do not indicate any association, influence, or effect of a particular variable on science achievement. Instead, the descriptive statistics of science achievement and say, gender, merely provided basic patterns or a general picture of the variables that placed subsequent inferential analyses within a broader context. To this end, the descriptive statistics provided an initial overview of the variables important to this study and were not used for drawing conclusions. That was reserved for the statistical parameters generated from the structural equation models.

*Sample Demographics*

The gender distribution for this study is presented in Table 4-1 and includes both weighted and unweighted percentages. For the sample of 5,854 children analyzed in this component of the study, 47.9% (n = 2,805) of them are males while 52.1% (n = 3,049) are females. With regard to the distribution of race and ethnicity, displayed in Table 4-2, the study sample is comprised of 60.5% white, non-Hispanic children (n = 3,540). A relatively equal number of black, non-Hispanic (7.2% or n = 421), Hispanic, race specified (7.4% or n = 431), and Hispanic race not specified (7.6% or n = 444) are found in the sample. In the sample of 5,854, Asians account for 4.2% or 248 children while Native, Pacific Islanders account for 1.0% (n = 60) and American Indian account for 1.3% (n = 77). 127 of the children (2.2%) are identified with more than one race and 506 of the children (8.6%) are missing data on their race and ethnicity.

Table 4-2 contains both the unweighted and weighted percentages for each racial and ethnic group.

As discussed in the previous chapter and worthy of mentioning again, the use of weighted averages made the appropriate adjustments necessary for data that is not a simple random sample. To indicate the relative strength of an observation, weights are applied to observations within the ECLS-K data set. In the most basic data set, each observation is counted equally, that is, each observation represents the same number of cases. For example, a simple random sample implies that every object or participant had an equal probability of being included in the study. In the ECLS-K data set, different cases or children have different probabilities of being selected due to the complex sampling of the population. Although the gender, racial, and ethnic make-up of the sample of 5,854 children analyzed in this study is helpful, beyond these demographic variables, the data reported from this point forward will only include the weight averages to make the appropriate adjustments for the complex sampling of the ECLS-K data set.

*Science Achievement*

A descriptive analysis was performed on the scientific achievement of the sample through third grade, fifth grade, and eighth grade science IRT scale scores. As discussed earlier, these three IRT scale scores assess the child's breadth and depth of science knowledge and understanding. Overall, the means and standard deviations for third, fifth, and eighth grade science IRT scale scores were found to be 53.3 ($SD$ = 14.5), 67.6 ($SD$ = 14.7), 86.5 ($SD$ = 14.7) respectively and displayed in Table 4-3. The weighted means and standard deviations were calculated to be 51.7 ($SD$ = 14.9), 65.6 ($SD$ = 15.4), and 84.6 ($SD$ = 15.7) and are also displayed in Table 4-3. Through a cursory inspection of Figure 4-1, there appeared to be a consistent increase or improvement in science achievement from the spring of third grade to the spring of eighth grade. A more formal and appropriate look at this trajectory appears later in this chapter. However, further descriptive analyses were run on the science achievement scores across the various subgroups of children (i.e., gender, race, ethnicity, SES, and disability status).

Again, beyond the sample demographics of gender and ethnicity and the sample descriptive statistics on overall science achievement presented above and in Tables 4-1 through 4-3 and Figure 4-1, the data reported from this point forward include only the weighted averages.

When achievement scores were separated by gender (Table 4-4), males scored averages of 53.9 (*SD* = 14.9), 68.2 (*SD* = 15.0), and 86.5 (*SD* = 15.4) across the three years of testing. Females scored 50.0 (*SD* = 14.4), 63.8 (*SD* = 15.3), and 83.4 (*SD* = 15.2). A visual comparison of male and female science achievement across the three assessment years is displayed in Figure 4-2.

Achievement scores separated by race and ethnicity are presented in Table 4-5 as well as Figure 4-3. Children reporting their race and ethnicity as white, non-Hispanic had relatively higher achievement scores for each of the three tested years followed by the other eight subgroups. Again, the discussion of these descriptive statistics is not meant to be inferential, but offer an overview of the achievement data. The statistical significance of these observations and IRT scale score differences were addressed in the growth curve analyses of this study.

With regard to socioeconomic status, Table 4-6 and Figure 4-4, the mean achievement scores of children from high SES families were 61.2 (*SD* = 13.0), 75.3 (*SD* = 12.1), and 94.2 (*SD* = 10.5), for each tested year. Children from middle SES families had average achievement scores of 52.4 (*SD* = 13.7), 66.7 (*SD* = 13.8), and 85.5 (*SD* = 14.2) while children from low SES families had scores of 39.4 (*SD* = 12.4), 52.7 (*SD* = 14.9), and 72.3 (*SD* = 16.9) for third, fifth, and eighth grade, respectively. Children with a disability status had achievement scores of 49.3 (*SD* = 15.8), 62.9 (*SD* = 16.8), and 80.7 (*SD* = 17.7) and those children without a disability had scores of 52.7 (*SD* = 14.7), 66.9 (*SD* = 14.9), and 86.0 (*SD* = 14.9) for the three tested grade levels (see Table 4-7 and Figure 4-5).

*Frequency, Duration, and Time Devoted to Elementary Science*

The teacher questionnaire associated with third grade asked teachers "how often do children in your class work on lessons or projects in science". The largest percent (41.3%) of teachers responded that they engaged in science "three or four times a week" followed by 34.8% stating "once or twice a week" and 18.6% reported "daily" science instruction. 4.8% reported that science occurred less than once a week and 0.5% responded with "never". Figure 4-6 summarizes the teachers' responses.

The same questionnaire also asked teachers "how much time do children in your class usually work on science". 63.0% of teachers that responded to this question indicated that 31 to 60 minutes a day was devoted to science followed by 32.4% stating that they spent 30 minutes or less per day. As shown in Figure 4-7, less than 5% reported over 60 minutes a day of science.

*Science Interest*

Much like the science achievement scores, a descriptive analysis was performed on the Academic Rating Scale (ARS) scores for science. However, this descriptive analysis focused on the science ARS score for eighth grade. As discussed in the previous chapter, the science interest variable for this study was the student’s ARS score from the eighth grade science teacher questionnaire. The types of questions found on the science ARS questionnaire are in line with the behaviors observed in students interested in science tasks (Good, 1983; Good & Beckerman, 1978; Young, Reynolds, & Walberg, 1996). Therefore, this study operationalized interest in science in the eighth grade by using the ARS science scores.

The ARS score was calculated using all responses provided by the teacher and converting the score to a scale score ranging from one to five where one indicates that the child has not yet demonstrated the necessary skills, knowledge, or behaviors in science and five indicates that child competently and consistently demonstrates the necessary skills, knowledge, and behaviors in science. What follows is a description of ARS science scores in general, and then separated by gender, race and ethnicity, socioeconomic status, and disability status.

As a continued word of caution, the descriptive analyses of ARS science scores provide an initial overview of the nature of the variables included in this study (i.e., distribution of the data and qualitative trends within certain variables). As a final note and re-emphasis, the reporting descriptive statistics for this variable across the various subgroups (i.e., gender, race and ethnicity, SES, and disability status) were not for the purpose of drawing inferential conclusions. Instead, the descriptive statistics associated with ARS science scores and demographic variables merely provided an opportunity to look at the basic patterns in ARS science scores.

The number of ECLS-K participants in this study that have a science ARS score is 2,743 and thus a subsample of the study sample of 5,854. This is due in part to the methodological implementation of the full-scale ECLS-K study. The NCES randomly selected fifty percent of the children to receive academic ratings from their eighth grade mathematics teacher while the remaining children were selected to receive academic ratings from their eighth grade science teacher (Tourangeau et al., 2009). Therefore, only half of the total ECLS-K participants have science ARS scores. Given the additional selection criteria applied specifically to this study, the number of children with eighth grade science ARS scores is approximately 47% or 2,743 children. Of those 2,743 children, 48.1% (n = 1,319) of them are males while 51.9% (n = 1,424) are females (see Table 4-8). With regard to the distribution of race and ethnicity, displayed in Table 4-9, the study sample was composed of 61.7% white, non-Hispanic children (n = 1,693). A relatively equal number of black, non-Hispanic (7.0% or n = 191), Hispanic, race specified (7.1% or n = 194), and Hispanic race not specified (7.0% or n = 192) are in the sample.  Within this subsample, Asians account for 3.9% or 107 children while Native, Pacific Islanders account for 0.9% (n = 26) and American Indian account for 1.3% (n = 35).  67 of the children (2.4%) are identified with more than one race and 238 of the children (8.7%) are missing data on their race and ethnicity.  Table 4-9 contains both the unweighted and weighted percentages for each racial and ethnic group.

A visual comparison of this subsample of 2,743 children with the study sample of 5,854 suggested that the demographic breakdown of the two sample populations is similar and does not differ significantly in terms of gender, racial, and ethnic make-up.

Teachers were asked to rate each child on his or her abilities and performance in the science classroom.  For example, science teachers were asked to rate the student's ability in organizing data, solving science problems, designing experiments, and talking or presenting about science.  Other questions addressed the specific behaviors of the student while in science class.  The behaviors included the number of times the student was tardy, how attentive he or she was while in class, how well the student engaged in activities, and the general disposition of the student towards the science class.  Overall, the mean and standard deviation for eighth grade science ARS scores was found to be 3.09 (*SD* = 1.01) and are displayed in Table 4-10.  The weighted mean and standard deviation was calculated to be 3.01 (*SD* = 1.00) and are also displayed in Table 4-10.  Further descriptive analyses were run on the eighth grade science ARS scores across the various subgroups of children (i.e., gender, race, ethnicity, SES, and disability status).

Again, beyond the sample demographics of gender and ethnicity and the sample descriptive statistics on the overall eighth grade science ARS scores presented above and in

Tables 4-8 through 4-10, the data reported from this point forward include only the weighted averages.

When eighth grade science ARS scores were separated by gender (Table 4-11), males scored an average of 2.90 (*SD* = 0.98). Females averaged 3.12 (*SD* = 1.00). A visual comparison of male and female scores is displayed in Figure 4-8.

Eighth grade science ARS scores separated by race and ethnicity are presented in Table 4-12 as well as Figure 4-9. Children reporting their race and ethnicity as Asian had relatively a higher average ARS score for eighth grade science followed by those children reporting multiple races, and students identifying themselves as white. Again, the discussion of these descriptive statistics is not meant to be inferential, but offer an overview of the ARS data. The statistical significance of these observations and ARS score differences were addressed in the final component of this study.

With regard to socioeconomic status, Table 4-13 and Figure 4-10, the mean ARS score in eighth grade science for children from high SES families was 3.50 (*SD* = 0.92). Children from middle SES families had an average ARS score of 3.00 (*SD* = 0.96) while children from low SES families had an average score of 2.39 (*SD* = 0.87). Children with a disability status had an average score of 2.44 (*SD* = 0.90) and those children without a disability had an average score of 3.11 (*SD* = 0.98) for the eighth grade science ARS (see Table 4-14 and Figure 4-11).

## Science Achievement Growth Curve Analysis

The second component of the analysis was a quantitative model of students' growth pattern in science achievement from spring of third grade to spring of eighth grade and the association of this growth with the frequency, duration, and time devoted to elementary science instruction in third grade. This consisted of the development and analysis of an unconditional growth model followed by the development and analysis of a conditional model that included both control variables (i.e., gender, race and ethnicity, SES, and disability status) and the frequency, duration, and time devoted to elementary science instruction in the third grade. What follows is the presentation of the results for both models that includes the model fit statistics (i.e., $\chi^2$, root-mean-square error approximation, normed fit index, and comparative fit index), growth trajectory estimates (e.g., the slope and intercepts of the growth curve), along with all relevant parameter estimates for both the control and predictor variables. As articulated in the presentation of results below, the model fit statistics informed post-analysis modifications to both the unconditional and conditional models. These post-hoc decisions were based on the fit statistics as well as the body of methodological literature associated with structural equation modeling and growth curve analyses that informed what modifications would be most helpful without distracting from neither the practicality of the results or the ability of the analysis to address the research questions of this study. Therefore, the presentation of results includes the initial models, the parameter estimates and fit statistics associated with each of the initial models, the post-analysis modifications made as a result of these values, and ends with the final models and their associated statistics. This provides readers with a complete description of all analytic decisions made in this study.

As mentioned in the methodology chapter, the standard errors generated for each of these models as well as the subsequent models by AMOS® 18 assume a simple random sample (SRS). However, the ECLS-K data set employs a complex design through the development of primary sampling units (PSUs). Therefore, it is necessary to calculate a design effect and correction factor for the standard errors generated in the AMOS® output. For each of the three waves of data utilized in this study, a cross-sectional design effect, or DEFT, was calculated to be 1.84, 2.04, and 1.83, respectively. An average DEFT value of 1.90 was used to correct standard error estimates. To correct for the complex design, the value of 1.90 was multiplied by the standard errors produced in the AMOS® output and new critical ratios were generated. In the end, the critical ratios did not significantly change and the *p* values associated with each estimate were virtually unaffected. This is not surprising in that a nested structure of children within assessment times is accounted for by the latent growth model analysis using structural equation modeling. However, in the interest of executing as strong a methodological approach as possible, the critical ration values reported in each of the model summaries is based on the corrected standard errors by the DEFT.

*Unconditional Model*

The unconditional model, developed to address the first research question, incorporated the science IRT scale scores for the spring of third grade (C5R2SSCL), spring of fifth grade (C6R2SSCL), and spring of eighth grade (C7R2SSCL). The analysis of this unconditional model provided a quantitative depiction of the growth pattern in science achievement by first assessing the nature of the growth pattern (linear, spline, or quadratic) as well as the data-model fit parameters. The development of such an unconditional model followed a series of post-analysis decisions that resulted in a final unconditional, spline, homoscedastic model of the growth trajectory for science achievement.

An initial model of science achievement was constructed in which the growth trajectory was assumed to be linear and the residual variances in achievement scores were left to be estimated in what are referred to as heteroscedasticity of errors or residual variances. This initial model represents one unconditional scenario for science achievement. That is, third grade science achievement was set to be the first assessment time and that specific regression weight for the slope set to be zero and the variance associated with this particular assessment was free to be estimated. The regression weight for the slope associated with 5$^{th}$ grade science achievement was set to two and 8$^{th}$ grade science achievement set to five and each of their variances were free to be estimated. This particular iteration of the unconditional model is shown in Figure 4-12 and a summary of the analysis including the parameter estimates as well as measures of goodness-of-fit are displayed in Table 4-15.

The model parameters for this unconditional, linear, heteroscedastic growth model were both significant at an alpha level of .001. The slope and intercept values were calculated to be 6.68 ($p < .001$) and 53.5 ($p < .01$), respectively. Thus, these two values are statistically different from zero and suggest statistically significant individual variation around the slope and intercepts. In other words, there appears to be statistically significant variation in the initial starting level and the growth slope in science achievement. Furthermore, the correlation between the slope and intercept was negative but found non-significant (-7.86, $p = .10$). Practically speaking, there appears to be no association between initial starting points and the rate of growth in science achievement. That is, students with lower initial starting points do not have statistically different growth rates than those students that have higher initial starting points in science achievement.

Multiple fit indices were utilized to evaluate how well this particular model fit the data. The $\chi^2$ value for this model was calculated to be 116.8 with 1 degree of freedom ($p < .001$). The $\chi^2$ statistic assesses the discrepancy between the original data matrix and the reproduced matrix implied by this unconditional, linear, heteroscedastic model. A non-significant $\chi^2$ test implies that there is either no discrepancy between the two matrices or that the discrepancy is not statistically significant (Klem, 2000). With regard to this specific model the $\chi^2$ statistic ($\chi^2$ = 116.8, $p < .001$) was statistically significant at an alpha level of .001. Additionally, the ratio of $\chi^2$ to degrees of freedom was also 116.8 given that the degrees of freedom are one. These two indices of overall fit indicated that there is a significant discrepancy between the original data matrix and the reproduced matrix from this unconditional model. Practically speaking, this would suggest that this iteration of the unconditional model in Figure 4-12, linear with heteroscedastic errors, is not a statistically strong fit for the data. However, Loehlin (2004) points out that the $\chi^2$ statistic, alone, is limiting as an indicator of overall model fit. The limitations of the $\chi^2$ statistic are due in part to the overall sensitivity of this statistic to sample size as well as multivariate non-normality (Bentler & Bonnett, 1980; Fan, Thompson, & Wang, 1999; Thompson, 2004; Klem, 2000; Loehlin, 2004). Most relevant to this analysis is the large sample size of 5,854 children. For large sample sizes (> 400), models are almost always rejected if based solely on the $\chi^2$ statistic (Klem, 2000; Bentler & Bonnett, 1980; Fan, Thompson, & Wang, 1999; Thompson, 2004). As Bentler and Bonnett (1980) point out, simply reducing the sample size reduces the $\chi^2$ value, making it statistically non-significant. For this specific analysis, the sample size would have needed to be reduced to 193 to obtain a non-significant result at an alpha level of .05 or 333 at an alpha level of .01 according to the Hoelter statistic for this model.

To address the limitations and instability of the $\chi^2$ statistic for a sample size as large as the one associated with this analysis ($n$ = 5,854), additional fit statistics were evaluated to better assess this initial model (i.e., RMSEA, NFI, and CFI). The root mean square error of approximation (RMSEA) which is robust to sample size, evaluates how well model parameters align with the overall population (Thompson, 2004). The RMSEA for this unconditional model was calculated to be .14. Guidelines on what is an acceptable or appropriate RMSEA generally agree that an RMSEA greater than .1 suggests a poor fitting model (Browne & Cudeck, 1993). More ideal values are less than .10 for a “good” model, less than .05 for a “very good” model (Steiger, 1989). Thompson (2004) is less specific but suggests any RMSEA around or less than .06 is an acceptable value. By all accounts, the RMSEA statistic of .14 seems to indicate that an unconditional linear, heteroscedastic model (Figure 4-12) is less than an optimal fit for this data.

Two additional fit indices, NFI and CFI, were also evaluated in determining the overall fit of the model in Figure 4-12. The normed fit index (NFI) is an assessment of a model compared to what Bentler and Bonnett (1980) refer to as a null model or a model that is an arbitrary model of the data. An NFI of one represents a perfect fit that is a statistically significant improvement from the arbitrary, baseline model. On the other hand, a value of closer to zero indicates that the model is statistically no different than an arbitrary baseline model. The NFI for the model presented in Figure 4-12 was determined to be .99, suggesting a better than average fit. Likewise, the comparative fit index or CFI was calculated to be .99 as well. The CFI compares the model to a baseline model but also assumes a non-central $\chi^2$ distribution (Thompson, 2004).

Given the somewhat inconsistent measures of model fit, the overall goodness-of-fit for the unconditional, linear, heteroscedastic model of science achievement appears to be in question. Slight modifications were made to this linear model in an attempt to provide an improved $\chi^2$ and RMSEA statistic. Given the large sample size of this study, obtaining a non-significant $\chi^2$ statistic seems unreasonable while a more ideal RMSEA statistic is not an unreasonable goal. One suggested modification is an examination of the residuals associated with the science IRT scale scores (Loehlin, 2004). Given that the focus of this study is on the individual variation in the trajectory of science achievement and not developing a model to account for the variance in science achievement scores in the 3$^{rd}$, 5$^{th}$, or 8$^{th}$ grade, imposing the condition of equal residual variances seems appropriate. Thus, the unconditional, linear model in Figure 4-12 was modified to contain homoscedastic errors (i.e., equal residual variances in science achievement) and is shown in Figure 4-13.

This second iteration of the unconditional model was constructed in which the growth trajectory was again assumed to be linear but the residual variances in achievement scores were constrained to be equal in what are referred to as homoscedastic errors or residual variances. Like the first iteration, 3rd grade science achievement was set to be the first assessment time and that specific regression weight for the slope set to be zero while the variance associated with this particular assessment was set to be equal to the residual variance associated with the 5th and 8th grade science IRT scale scores (i.e., all three residual variances are constrained to be equal). The regression weight for the slope associated with 5th grade science achievement was set to two and 8th grade science achievement set to five and each of their variances were set to be equal as well. These equal residuals are labeled with a lower case *e* in Figure 4-13. A summary of the analysis including the parameter estimates as well as measures of goodness-of-fit for this adjusted unconditional model are displayed in Table 4-16.

The model parameters for this unconditional, linear, homoscedastic growth model were also significant at an alpha level of .001. The slope and intercept values were calculated to be 6.65 ($p < .001$) and 53.7 ($p < .001$), respectively. Thus, these two values continue to be statistically different from zero and suggest statistically significant individual variation around the slope and intercepts. As with the previous model, there continues to be statistically significant variation in the initial starting level and the growth slope in science achievement. The correlation between the slope and intercept remained negative and this time was significant at an alpha level of .01 (-5.31, $p = .009$). Unlike the previous model, this iteration indicates that students starting out with lower initial achievement scores in science have a higher rate of growth than those students starting out with higher initial achievement levels.

How well this modified model fit the data was evaluated using the same fit indices as in the previous model to provide a comparison of model fit in light of the modification of homoscedastic errors. The $\chi^2$ value for this model was calculated to be 177.8 with 3 degree of freedom ($p < .001$). A statistically significant discrepancy still exists between the original data matrix and the matrix reproduced by the model. With regard to this specific model the $\chi^2$ statistic ($\chi^2$ = 177.8, $p < .001$) was statistically significant at an alpha level of .001. Additionally, the ratio of $\chi^2$ to degrees of freedom was 59.3 and still indicative of poor fit. This would suggest that this iteration of this unconditional model in Figure 4-13, linear with homoscedastic errors, is not a statistically strong fit for the data. However, the issue of sample size remains for this model. Thus, the aim of modifying the model is to reduce the $\chi^2$ value and bring additional fit indices (i.e., RMSEA) within acceptable limits as suggested in the literature (e.g., Brown & Cudeck, 1993; Steiger, 1989; Thompson, 2004). For this specific analysis, the sample size would have needed to be reduced to 258 to obtain a non-significant result at an alpha level of .05 or 374 at an alpha level of .01 according to the Hoelter statistic for this model.

The RMSEA for this unconditional model was calculated to be .10. This particular value is on the threshold of what is considered a poor fitting model (Brown & Cudeck, 1993). As in the previous model, the $\chi^2$ statistic and the RMSEA are inconsistent with the NFI and the CFI. The NFI for the model presented in Figure 4-13 was calculated at .99 suggesting a better than average fit. Likewise, the comparative fit index or CFI was calculated to be .99 as well.

Given the increase in the $\chi^2$ statistic and a less than optimal value of .10 for an RMSEA, the overall goodness-of-fit for the unconditional, linear, homoscedastic model of science achievement remains average at best. The literature surrounding growth curve analysis often suggests that large sample sizes make these models highly sensitive to any deviation in the nature of the growth trajectory. In other words, if the growth pattern differs even slightly from a linear path, a large sample size will exacerbate this deviation and indicate a poor fitting model (Loehlin, 2004; Thompson, 2004). Referring back to Figure 4-1, the trajectory of science IRT scale scores appears to deviate from a purely linear path. Therefore, the modification of this linear model to a spline model may provide a more significant reduction in the $\chi^2$ statistic as well as a better RMSEA value. The unconditional, linear model in Figure 4-13 was modified a second time to a spline model freeing up the second time pattern coefficient to be estimated while still restricting the residual variances to being equal (homoscedastic errors). This third iteration of the model is shown in Figure 4-14.

This third iteration of the unconditional model was constructed in which the growth trajectory was not restricted to a linear pattern. Although the residual variances in achievement scores were still constrained to be equal, the pattern coefficient for the second assessment (i.e., $5^{th}$ grade science IRT scale score) was unconstrained in the model. Put differently, the pattern coefficients associated with time of assessments were modified from 0, 2, and 5 which represented the time in years for each assessment (i.e., 0 as the starting point, 2 indicates an assessment two years later, and 5 indicates an assessment five years from the starting point) to 0, unconstrained, and 5. This freed up the model to estimate the pattern coefficient associated with the second assessment time and thus the flexibility to model a non-linear growth pattern. A summary of the analysis including the parameter estimates as well as measures of goodness-of-fit are displayed in Table 4-17.

The model parameters for this unconditional, spline, homoscedastic growth model were both significant at an alpha level of .001. The slope and intercept values were calculated to be 6.68 ($p < .001$) and 53.3 ($p < .001$), respectively. Thus, these two values were again statistically different from zero and suggest statistically significant individual variation around the slope and intercepts. As with the previous models, there is statistically significant variation in the initial starting level and the growth slope in science achievement. Furthermore, the correlation between the slope and intercept remained negative and was significant at an alpha level of .05 (-5.42, $p = .02$). The pattern coefficient associated with the second assessment time was found to be 2.14 ($p <.001$). This suggests that the growth pattern is non-linear.

How well this modified model fit the data was evaluated using the same fit indices as in the previous models to provide a comparison of model fit in light of the modification of a spline trajectory. The $\chi^2$ value for this model was calculated to be 79.0 with 2 degree of freedom ($p <$ .001). A statistically significant discrepancy still exists between the original data matrix and the matrix reproduced by the model. However, it is relatively smaller than the two previous models. With regard to this specific model the $\chi^2$ statistic ($\chi^2$ = 79.0, $p <$ .001) was statistically significant at an alpha level of .001. Additionally, the ratio of $\chi^2$ to degrees of freedom was reduced to 39.5 although still indicative of poor fit. The sample size would have needed to be reduced to 444 to obtain a non-significant result at an alpha level of .05 or 683 at an alpha level of .01 according to the Hoelter statistic for this model. This would suggest that this iteration of this unconditional model in Figure 4-14, spline with homoscedastic errors, is not a statistically strong fit for the data but a significant improvement from the two previous models given the large sample analyzed in this study.

The RMSEA for this unconditional model was calculated to be .08. This particular value is below threshold of what is considered a poor fitting model (Brown & Cudeck, 1993). The $\chi^2$ statistic and the RMSEA value are more consistent with the NFI and the CFI for this third iteration. The NFI for the model presented in Figure 4-14 was found to be .99 suggesting a better than average fit. Likewise, the comparative fit index or CFI was calculated to be .99 as well.

Overall, the unconditional, spline, homoscedastic model appears to be the best fit for the growth trajectory of science achievement based on the aggregate assessment of both the model fit indices as well as the $\chi^2$ change associated with each modification of the original model. In this case with a sample size greatly exceeding 400, the appropriateness of the model is best evaluated by the change in the $\chi^2$ statistic and the degrees of freedom after such modifications are made. Table 4-18 provides a line-by-line comparison of the three unconditional models as well as the $\chi^2$ difference statistic comparing the first two models with the spline, homoscedastic model. As highlighted in yellow, the modification of the growth trajectory from linear to spline resulted in a statistically significant reduction in the $\chi^2$ value at an alpha level of .001. Furthermore, the final iteration of the model indicates a better RMSEA value than the two previous models. The assessment of a quadratic growth trajectory is not necessary given that the general pattern is far from quadratic and, more importantly, there are only three time-variant data points (i.e., three assessments) in the model.

Taken together, the growth trajectory in science achievement scores appears to be non-linear with statistically significant individual variation around both the starting point (intercept) and the growth (slope) in science achievement. What is also consistent across all three iterations of the unconditional model is the negative correlation of the slope and intercept. The significance of this correlation in the final unconditional model indicates that those students with lower initial values of science IRT scale scores seem to have the largest growth in science achievement over the three assessments. On the other hand, those students with higher initial values of science IRT scale scores seem to have the smallest growth in science achievement over the three assessments. A more thorough discussion of the implications of this unconditional trajectory analysis is presented in the next chapter. The next step presented in this analysis was the attempt to identify what predictors could account for such individual variations in the slop and intercept of the growth trajectories. By including the control variables of race, ethnicity, SES, and disability status along with the predictor variables of frequency, duration, and time devoted to elementary science instruction in the third grade, is there a reduction in the amount of individual variation in the starting points and growth in science IRT scale scores?

*Conditional Model*

Using the unconditional, spline, homoscedastic model, the dummy variables generated from the composite variables for gender (R7GENDER), race and ethnicity (W8RACETH), SES (W8SESQ5), and disability status (P7DISABL) were added to the model as covariates along with the two predictor variables frequency (A5OFTSCI) and duration (A5TXSCI) of science in third grade. This initial conditional model is presented in Figure 4-15.

The model parameters for the conditional growth model along with the model fit statistics are displayed in Table 4-19. The slope and intercept, 6.73 ($p < .001$) and 47.3 ($p < .001$) respectively, were both significant at an alpha level of .001. Thus, these two values are again statistically different from zero and suggest statistically significant individual variation around the slope and intercepts. As with the unconditional model, there is statistically significant variation in the initial starting level and the growth slope in science achievement. Furthermore, the correlation between the slope and intercept remained negative and was significant at an alpha level of .001 (-5.04, $p < .001$). With regard to the control variables the effects associated with gender, SES, and disability status were statistically significant and contributed to the reduction of the amount of individual variation in initial achievement scores but not achievement growth. Likewise, many of the race and ethnicity variables were statistically significant with a few exceptions. The unstandardized and standardized effects are presented in Table 4-20.

Although gender, race, ethnicity, SES, and disability status served as control variables for this study, the specific influence of these variables on the growth curve of science achievement contributes to the overall purpose of the study. Specifically, the influence of gender on the initial science IRT scale scores was -4.38 ($p < .001$) suggesting that females have lower initial starting points in terms of science achievement. On the other hand, the females show no significant difference in their growth in science achievement when compared to males. Students reporting a disability also showed a lower initial starting point (-4.11, $p < .001$) but no statistical difference in the rate of growth compared to those students reporting no disability ($p > .05$). Compared to students from low socioeconomic backgrounds, students reporting middle and high SES demonstrated a similar trend with a significant intercept (7.87, $p < .001$ and 14.5, $p < .001$, respectively), but non-significant slope.

The breakdown across the race and ethnicity subgroups was not as consistent across the subgroups as a whole. Those students identified as members of more than one racial and ethnic group did not have a significantly different initial starting point or a statistically different growth rate when compared to white children. Each of the other subgroups (i.e., African Americans, Hispanics, Asians, Pacific Islanders, and Native Americans) indicated a negative influence on the initial starting point for science achievement based on the science IRT scale scores with parameter estimates of -12.2 ($p < .001$) for African Americans, -7.56 ($p < .001$) for Hispanics, race specified, -9.76 ($p < .001$) for Hispanics, race not specified, -3.98 ($p = .01$) for Asians, -12.3 ($p < .001$) for Pacific Islanders, -8.46 ($p = .002$) for Native Americans. Practically speaking, these parameter estimates indicate that when these subgroups were compared to white students, they had significantly lower initial science IRT scale scores. However, the two Hispanic subgroups and the Asian subgroup had significantly higher growth rates in science achievement compared with white students (.506, $p = .02$, .491, $p = .02$, and .591, $p = .03$). The growth rate associated with African Americans, Pacific Islanders, and Native Americans was not found to be significantly different from white students.

The two predictor variables associated with this conditional model produced parameter estimates indicated that the frequency of science in the third grade was statistically significant and the duration of science in the third grade was not. The influence of frequency in third grade science was positive (1.06) and significant with a *p* value of .01. In other words, students that had "science class" more frequently in the third grade had a higher initial science IRT scale score. With regard to the growth rate in science achievement, the influence was negative, but non-significant. The implications of this finding will be discussed in great length in the next chapter as these results require both cautious interpretation and discussion.

How well the conditional model fit the data was evaluated using the same fit indices as in the previous models (see Table 4-19). The $\chi^2$ value for this model was calculated to be 5775.7 with 93 degrees of freedom ($p < .001$). A statistically significant discrepancy exists between the original data matrix and the matrix reproduced by the conditional model. This strongly suggests a poor fitting model. Additionally, the ratio of $\chi^2$ to degrees of freedom 62.1 and was also indicative of poor fit. The sample size would have needed to be reduced to 119 to obtain a non-significant result at an alpha level of .05 or 130 at an alpha level of .01 according to the Hoelter statistic for this model. This would suggest that this iteration of this conditional model in Figure 4-15, is not a statistically strong fit for the data.

The RMSEA for this conditional model was calculated to be .10. This particular value is on the threshold of what is considered a poor fitting model (Brown & Cudeck, 1993). The $\chi^2$ statistic and the RMSEA were consistent with the NFI and the CFI. The NFI for the model presented in Figure 4-15 was calculated to be .71, suggesting a below average fit. Likewise, the comparative fit index or CFI was calculated to be .71 as well.

Taken together, the model fit indices indicated a poor fitting model. Several post-analytic decisions were made to improve the model fit and thus the statistical power of this component of the analysis. A series of modifications were made to the above conditional model. First, in the interest of obtaining the most parsimonious model, those parameters that were found non-significant were eliminated from the model. Those students that were identified as being from more than one racial or ethnic group were not a significant control variable and that path in the model was eliminated. Second, several race and ethnicity groupings were collapsed into larger categories due to the small number of students within the group. For example, Hispanic, race specified and Hispanic, race not specified were combined into a single group, Hispanic. In addition, Pacific Islanders were combined with Native Americans to form a single subgroup. A third modification recoded the SES composite variable into two groups, high and low SES, rather than the three groups suggested by the NCES. Finally, the duration of science in the third grade was eliminated from the model due to the non-significant result in the initial model. This modified conditional model is presented in Figure 4-16.

The parameters for this modified conditional model (see Table 4-21) indicated a continued statistically significant slope of 6.92 ($p < .001$) and intercept of 54.0 ($p < .001$). The correlation between the slope and intercept remained significant as well with a value of -4.84 ($p < .001$). As with each of the previous models, there is statistically significant individual variation around the starting point of science achievement as measured by science IRT scale scores as well as individual growth rates.

The control and predictor variable associated with this reduced model are displayed, along with their unstandardized and standardized effects, in Table 4-22. The influence of gender on the initial science IRT scale scores was found to be -4.48 ($p < .001$) again suggesting that females have lower initial starting points in terms of science achievement. On the other hand, the females again showed no difference growth in science achievement when compared to males ($p > .05$). The influence of gender on the starting point and growth trajectory of science achievement resembles the previous conditional model. This is also the case for students reporting a disability, which indicated a lower initial starting point (-4.41, $p < .001$) and a non-significant difference in rate of growth, compared to those students reporting no disability. Compared to students from low socioeconomic backgrounds, students identified as high SES had higher initial starting points (7.68, $p < .001$), but did not show a statistically different growth rate in science achievement.

The breakdown across the modified race and ethnicity subgroups followed a similar trend as the previous conditional model. Each of the subgroups (i.e., African Americans, Hispanics, Asians, and Pacific Islanders/Native Americans) produced a negative influence on the initial starting point for science achievement based on the science IRT scale scores with parameter estimates of -13.8 ($p < .001$) for African Americans, -10.9 ($p < .001$) for Hispanics, -4.86 ($p = .003$) for Asians, and -10.8 ($p < .001$) for Pacific Islanders/Native Americans. As with the previous model, these parameter estimates indicate that when these subgroups are compared to white students, they have significantly lower initial science IRT scale scores. The African American and Pacific Islander/Native American subgroup did not have a statistically different growth rate when compared to white students. Each of the remaining subgroups (Hispanics, and Asians) did (.434, $p < .007$, and .567, $p < .04$).

The predictor variables remaining in this modified conditional model produced parameter estimates suggesting that the frequency of science in the third grade was statistically significant. The influence of frequency in third grade science was positive (1.03) and significant with a $p$ of .02. In other words, students that had “science class” more frequently in the third grade had a higher initial science IRT scale score. With regard to the growth rate in science achievement, the influence was negative and non-significant. This seems to suggest that those students that have more science more frequently do not have a statistically different growth rate than those that have fewer science classes. The implications of this finding will be discussed in great length in the next chapter as these results require both cautious interpretation and discussion.

The parameter estimates and the effects associated with the control and predictor variables are quite similar between the two models. The most striking difference between the original conditional model and the reduced or modified conditional model was the model fit. A comparison of these two models is presented in Table 4-23. The $\chi^2$ value for the modified model was calculated to be 758.4 with 38 degrees of freedom ($p < .001$). Although a statistically significant discrepancy still exists between the original data matrix and the matrix reproduced by the conditional model, there was a reduction in the $\chi^2$ value by 5017.3 ($p < .001$) and degrees of freedom by 55. This suggests significant model improvement in spite of the ratio of $\chi^2$ to degrees of freedom 20.0 and a sample size outside of the limits indicated by the Hoelter statistic (119, $p < .05$ or 130, $p < .01$).

Furthermore, the RMSEA for this modified conditional model was reduced to .06. This particular value is in line with what is considered a good fitting model (Brown & Cudeck, 1993). The $\chi^2$ statistic and the RMSEA were consistent with the NFI and the CFI. The NFI for the model was increased to .95, suggesting an above average fit. Likewise, the comparative fit index or CFI was also calculated to be .95. The statistically significant reduction in the $\chi^2$ statistic along with the greatly improved fit statistics, the reduced and modified model presented in Figure 4-16 is a more optimal choice for exploring the covariates and predictors that account for the individual variations around the initial starting point in science achievement and growth rates. The variance associated with the intercept and slope in the conditional model were calculated to be 182.5 and 1.85, respectively. The variances associated with these two parameters in the final conditional model were calculated to be 129.0 and 1.77. Thus, the inclusion of predictor and control variables (e.g., gender, race and ethnicity, SES, disability status, and frequency of science in the third grade) in the final conditional model accounted for a 29.3% reduction in intercept variance and 4.32% reduction in slope variance. The discussion and implications of this analysis are presented in the next chapter.

As a final attempt at improving the model fit of the conditional model, consideration was given to the potential correlation between socioeconomic status and disability status. Conceptually, this potential association or relationship is suggested in the literature on students with identified disabilities (Lerner & Kline, 2006). However, when this correlation was placed in the modified conditional model, it provided no statistical improvement to the model fit nor was there a statistically significant correlation between the two variables. Thus, the correlation was left out of the final model.

## Science Interest Model Analysis

A linear regression model, shown in Figure 4-17, was developed in AMOS® 18 to evaluate the influence of frequency and duration on science engagement as assessed during the spring of eighth grade. As discussed in the previous chapter, the continued use of AMOS® 18 for a model that could just as easily be analyzed in a more basic program was to maintain the consistent handling of missing data.

The regression weights (see Table 4-24) produced by this model indicated that the frequency and duration of science in the third grade was not significantly associated with assessed student engagement in eighth grade science. However, gender, SES, and disability status were all significantly associated with eighth grade science engagement as measured through the science academic rating scale scores. Females were had higher science ARS scores compared to males in the eighth grade (.161, $p$ = .02). With regard to socioeconomic status, students classified as having above average SES had higher eighth grade science ARS scores compared to those students coming from lower SES backgrounds (.484, $p$ < .001). A similar trend was found for students with an identified disability. Students reporting a disability scored lower on the science ARS compared with those students reporting no disability (-.593, $p < .001$).

African Americans and Hispanics all had lower eighth grade science ARS scores compared to white students (-.504, $p < .001$ and -.386, $p < .001$). Pacific Islanders also had lower ARS scores (-.395, $p = .045$). Asian students showed no significant difference in science ARS scores when compared to white students (i.e., all $p$ values > .05).

From this final component of the analysis, the results suggest that the frequency of science in the third grade was not associated with engagement and interest in the eighth grade. Instead, the influence on engagement and interest was statistically associated with demographic variables.

## Summary of Findings

The results presented in this chapter sought to address each of the three research questions associated with this study. The first question presented in this study sought to describe the growth pattern of science achievement between the spring of 3rd grade and the spring of 8th grade of first-time kindergarteners. The results of the unconditional growth model indicated that the specific growth pattern is non-linear in nature and that there is significant individual variation around the initial starting point of science achievement as well as the individual growth rates in achievement. Moreover, the relationship between the initial starting point in science achievement and the growth rate was found to be negative. This implies that students' with lower initial science IRT scale scores demonstrated a more rapid growth rate than those students with higher initial science IRT scale scores. To gain a better understanding of what factors or variables explain the significant individual variation around the initial starting points and growth rate, a conditional model is needed.

The second research question sought to identify the influence of frequency and duration of science in the third grade on the growth pattern of science achievement above and beyond demographic variables (i.e., gender, race and ethnicity, SES, and disability status). The results of the conditional model suggested that the frequency of science in the third grade was a significant variable in explaining the individual variations the initial starting points of science achievement, but failed to explain the individual variations in growth rates. On the other hand, the duration of science instruction was found to be a non-significant contributor to either components of the growth trajectory. An additional outcome of this analysis was the association of various demographic subgroups with variations in the growth trajectories. For example, many demographic subgroups showed significant differences in the initial starting points of science achievement but did not show significant differences in the growth rate. These results suggest a lack of “catching-up” for students with lower starting points in science achievement. A more optimistic viewpoint would be that these students simply enter at different starting points, but there rates of growth are statistically equal.

Prior research has looked at both the importance of frequent opportunities of students to experience early formal science education (Driver et al., 1994; Ravanis & Bagakis, 1998; French, 2004; Gelman & Brenneman, 2004; Rahayu & Tytler, 1999; Tytler & Peterson, 2003) as well as the differences in science achievement across gender, different races and ethnic groups, and SES (Lee & Buxton, 2008; Spelke, 2005; Iverson & Walberg, 2002). However, this work does not address the long-range influence of these early experiences or the longitudinal achievement of the various subgroups. These results contribute to the understanding of the science achievement trajectories of students beyond cross-sectional analyses. Although there are many variables that contribute to an individual student’s achievement trajectory in science, the results of this analysis suggest that the frequency of science in the 3rd grade, elementary school classroom, along with demographic characteristics play a role in the initial achievement of students as well as their growth rate in science.

The final research question addressed the influence of the frequency and duration of science instruction in 3rd grade on long-range interest and engagement in science. Although the frequency of science in the 3rd grade appeared to have an effect on the growth trajectory of achievement, this variable and the duration of science in the 3rd grade did not have a significant impact on interest and engagement in 8th grade science. The interest and engagement in 8th grade science was found to be associated more so with gender, race and ethnicity, SES, and disability status.

**Table 4-1**

***Unweighted and Weighted Gender Distribution***

| Gender | n | Unweighted % | Weighted % |
|---|---|---|---|
| Male | 2805 | 47.9 | 49.2 |
| Female | 3049 | 52.1 | 50.8 |
| Total | 5854 | 100 | 100 |

**Table 4-2**

***Unweighted and Weighted Race and Ethnicity Distribution***

| Race / Ethnicity | n | Unweighted % | Weighted % |
|---|---|---|---|
| White, Non-Hispanic | 3540 | 60.5 | 53.9 |
| Black, Non-Hispanic | 421 | 7.2 | 12.6 |
| Hispanic, Race Specified | 431 | 7.4 | 8.4 |
| Hispanic, Race Not Specified | 444 | 7.6 | 8.9 |
| Asian | 248 | 4.2 | 2.3 |
| Native, Pacific Islander | 60 | 1 | 0.4 |
| American Indian, Alaska | 77 | 1.3 | 1.1 |
| More Than One Race, Non-Hispanic | 127 | 2.2 | 1.9 |
| Missing | 506 | 8.6 | 10.5 |
| Total | 5854 | 100 | 100 |

**Table 4-3**

***Mean Science IRT Scale Scores, No Factors Included***

| Mean Science IRT-Score (No Factors Included) | | | | |
|---|---|---|---|---|
| | **Unweighted** *Mean (SD)* | **Weighted** *Mean (SD)* | ***Minimum*** | ***Maximum*** |
| **Spring of 3rd Grade** | 53.4 (14.5) | 51.9 (14.8) | 18.2 | 95.4 |
| **Spring of 5th Grade** | 67.7 (14.6) | 65.9 (15.3) | 22.6 | 103.2 |
| **Spring of 8th Grade** | 86.8 (14.4) | 84.9 (15.4) | 28.3 | 108.0 |

**Table 4-4**

***Weighted Mean Science IRT Scale Scores by Gender Compared with Overall Weighted Scores***

| Mean Science IRT-Score by Gender, Weighted | | | |
|---|---|---|---|
| | **No Factors** | **Males** | **Females** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 3rd Grade** | 51.9 (14.8) | 53.9 (14.9) | 50.0 (14.4) |
| **Spring of 5th Grade** | 65.9 (15.3) | 68.2 (15.0) | 63.8 (15.3) |
| **Spring of 8th Grade** | 84.9 (15.4) | 86.5 (15.4) | 83.4 (15.2) |

**Table 4-5**

***Weighted Mean Science IRT Scale Scores by Race and Ethnicity Compared with Overall Weighted Scores***

| Mean Science IRT-Score by Race and Ethnicity, Weighted | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No Factors | White | Black | Hispanic, Race | Hispanic, No Race | Asian | Pacific Islander | American Indian | Multiple | No Response |
| | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* | *Mean (SD)* |
| **Spring of 3rd Grade** | 51.9 (14.8) | 57.4 (13.4) | 41.0 (12.6) | 46.9 (14.0) | 42.6 (12.2) | 52.5 (16.7) | 44.9 (10.7) | 45.7 (13.0) | 54.3 (11.1) | 49.3 (13.7) |
| **Spring of 5th Grade** | 65.9 (15.3) | 71.3 (12.7) | 53.6 (15.5) | 62.0 (14.8) | 62.0 (14.8) | 66.7 (18.1) | 57.0 (11.8) | 59.2 (15.2) | 67.9 (11.3) | 62.8 (15.2) |
| **Spring of 8th Grade** | 84.9 (15.4) | 90.1 (12.5) | 71.8 (16.6) | 81.6 (15.2) | 81.6 (15.2) | 88.5 (14.6) | 79.0 (15.7) | 79.2 (17.7) | 86.6 (11.4) | 82.3 (14.9) |

**Table 4-6**

***Weighted Mean Science IRT Scale Scores by SES Compared with Overall Weighted Scores***

| Mean Science IRT-Score by SES, Weighted | | | | | |
|---|---|---|---|---|---|
| | **No Factors** | **Low SES** | **Middle SES** | **High SES** | **No Response** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 3rd Grade** | 51.9 (14.8) | 39.4 (12.4) | 52.4 (13.7) | 61.2 (13.0) | 49.1 (13.6) |
| **Spring of 5th Grade** | 65.9 (15.3) | 52.7 (14.9) | 66.7 (13.8) | 75.3 (12.1) | 62.7 (15.3) |
| **Spring of 8th Grade** | 84.9 (15.4) | 72.3 (16.9) | 85.5 (14.2) | 94.2 (10.5) | 82.2 (14.9) |

**Table 4-7**

***Weighted Mean Science IRT Scale Scores by Disability Status Compared with Overall Weighted Scores***

| Mean Science IRT-Score by Disability Status, Weighted | | | | |
|---|---|---|---|---|
| | **No Factors** | **Diability** | **No Disability** | **No Response** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 3rd Grade** | 51.9 (14.8) | 49.3 (15.8) | 52.7 (14.7) | 49.3 (13.6) |
| **Spring of 5th Grade** | 65.9 (15.3) | 62.9 (16.8) | 66.9 (14.9) | 62.9 (15.2) |
| **Spring of 8th Grade** | 84.9 (15.4) | 80.7 (17.7) | 86.0 (14.9) | 82.4 (14.8) |

**Table 4-8**

***Unweighted and Weighted Gender Distribution for the ARS Subsample***

| Gender | n | Unweighted % | Weighted % |
|---|---|---|---|
| Male | 1319 | 48.1 | 48.3 |
| Female | 1424 | 51.9 | 51.7 |
| Total | 2743 | 100.0 | 100.0 |

**Table 4-9**

***Unweighted and Weighted Race and Ethnicity Distribution for the ARS Subsample***

| Race / Ethnicity | n | Unweighted % | Weighted % |
|---|---|---|---|
| White, Non-Hispanic | 1693 | 61.7 | 59.1 |
| Black, Non-Hispanic | 191 | 7.0 | 14.6 |
| Hispanic, Race Specified | 194 | 7.1 | 9.6 |
| Hispanic, Race Not Specified | 192 | 7.0 | 9.4 |
| Asian | 107 | 3.9 | 2.6 |
| Native, Pacific Islander | 26 | 0.9 | 0.6 |
| American Indian, Alaska | 35 | 1.3 | 1.5 |
| More Than One Race, Non-Hispani | 67 | 2.4 | 2.4 |
| Missing | 238 | 8.7 | 0.3 |
| Total | 2743 | 100.0 | 100.0 |

**Table 4-10**

***Mean Science ARS Scores, No Factors Included***

| | Mean Science ARS Score (No Factors Included) | | | |
|---|---|---|---|---|
| | **Unweighted** ***Mean (SD)*** | **Weighted** ***Mean (SD)*** | ***Minimum*** | ***Maximum*** |
| **Spring of 8th Grade** | 3.09 (1.01) | 3.01 (1.00) | 1.04 | 4.96 |

**Table 4-11**

***Weighted Mean Science ARS Scores by Gender Compared with Overall Weighted Scores***

| Mean Science ARS Score by Gender, Weighted | | | |
|---|---|---|---|
| | **No Factors** | **Males** | **Females** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 8th Grade** | 3.01 (1.00) | 2.90 (.98) | 3.12 (1.00) |

**Table 4-12**

***Weighted Mean Science ARS Scores by Race and Ethnicity Compared with Overall Weighted Scores***

| Mean Science ARS Score by Race and Ethnicity, Weighted | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **No Factors** | **White** | **Black** | **Hispanic, Race** | **Hispanic, No Race** | **Asian** | **Pacific Islander** | **American Indian** | **Multiple** | **No Response** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 8th Grade** | 3.01 (1.00) | 3.20 (.97) | 2.54 (.84) | 2.71 (1.05) | 2.73 (1.00) | 3.69 (.96) | 2.52 (.89) | 2.86 (1.08) | 3.22 (.81) | 2.84 (.66) |

**Table 4-13**

***Weighted Mean Science ARS Scores by SES Compared with Overall Weighted Scores***

| | Mean Science ARS Score by SES, Weighted | | | |
|---|---|---|---|---|
| | **No Factors** | **Low SES** | **Middle SES** | **High SES** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 8th Grade** | 3.01 (1.00) | 2.39 (.87) | 3.00 (.96) | 3.50 (.92) |

**Table 4-14**

***Weighted Mean Science ARS Scores by Disability Status Compared with Overall Weighted Scores***

| Mean Science ARS Score by Disability Status, Weighted | | | | |
|---|---|---|---|---|
| | **No Factors** | **Diability** | **No Disability** | **No Response** |
| | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** | ***Mean (SD)*** |
| **Spring of 8th Grade** | 3.01 (1.00) | 2.44 (.90) | 3.11 (.98) | 2.86 (1.07) |

**Table 4-15**

***Model Summary for Unconditional, Linear, Heteroscedastic Growth Trajectory***

| Growth Trajectory Estimates | Linear, Heteroscedastic | |
|---|---|---|
| Pattern Coefficients | 1, 0 | |
| | 1, 2 | |
| | 1, 5 | |
| Intercept | 53.5 (149.0)[a] | ** |
| Intercept Variance | 190.6 (23.7) | * |
| Slope | 6.68 (125.6) | ** |
| Slope Variance | 2.75 (6.06) | ns |
| Intercept-Slope Covariance | -7.86 (-6.51) | ns |
| Intercept-Slope Correlation | -0.343 | |
| **Fit Statistics** | | |
| $\chi^2$ | 116.8 | *** |
| Degrees of Freedom (df) | 1 | |
| RMSEA | 0.14 | |
| NFI | 0.99 | |
| CFI | 0.99 | |
| Hoelter | 193 (.05) | |
| | 333 (.01) | |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-16**

***Model Summary for Unconditional, Linear, Homoscedastic Growth Trajectory***

| Growth Trajectory Estimates | Linear, Homoscedastic | |
|---|---|---|
| Pattern Coefficients | 1, 0 | |
| | 1, 2 | |
| | 1, 5 | |
| Intercept | 53.7 (148.7)[a] | *** |
| Intercept Variance | 181.8 (24.4) | *** |
| Slope | 6.65 (120.7) | *** |
| Slope Variance | 1.82 (9.30) | ** |
| Intercept-Slope Covariance | -5.31 (-6.08) | ** |
| Intercept-Slope Correlation | -0.293 | |
| **Fit Statistics** | | |
| $\chi^2$ | 177.8 | *** |
| Degrees of Freedom (df) | 3 | |
| RMSEA | 0.1 | |
| NFI | 0.99 | |
| CFI | 0.99 | |
| Hoelter | 258 (.05) | |
| | 374 (.01) | |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-17**

***Model Summary for Unconditional, Spline, Homoscedastic Growth Trajectory***

| Growth Trajectory Estimates | Spline, Homoscedastic | |
|---|---|---|
| Pattern Coefficients | 1, 0 | |
| | 1, 2.14 (80.5) | *** |
| | 1, 5 | |
| | | |
| Intercept | 53.3 (144.6)[a] | *** |
| Intercept Variance | 182.5 (24.4) | ** |
| Slope | 6.68 (121.2) | *** |
| Slope Variance | 1.85 (9.45) | * |
| Intercept-Slope Covariance | -5.42 (-4.70) | * |
| Intercept-Slope Correlation | -0.296 | |
| | | |
| **Fit Statistics** | | |
| $\chi^2$ | 79 | *** |
| Degrees of Freedom (df) | 2 | |
| RMSEA | 0.08 | |
| NFI | 0.99 | |
| CFI | 0.99 | |
| Hoelter | 444 (.05) | |
| | 683 (.01) | |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-18**

***Model Comparison for the Three Unconditional Growth Pattern Analyses***

| Growth Trajectory Estimates | Linear, Heteroscedastic | | Linear, Homoscedastic | | Spline, Homoscedastic | |
|---|---|---|---|---|---|---|
| Pattern Coefficients | 1, 0 | | 1, 0 | | 1, 0 | |
| | 1, 2 | | 1, 2 | | 1, 2.14 (80.5) | *** |
| | 1, 5 | | 1, 5 | | 1, 5 | |
| Intercept | 53.5 (149.0)[a] | ** | 53.7 (148.7)[a] | *** | 53.3 (144.6)[a] | *** |
| Intercept Variance | 190.6 (23.7) | * | 181.8 (24.4) | *** | 182.5 (24.4) | ** |
| Slope | 6.68 (125.6) | ** | 6.65 (120.7) | *** | 6.68 (121.2) | *** |
| Slope Variance | 2.75 (6.06) | ns | 1.82 (9.30) | ** | 1.85 (9.45) | * |
| Intercept-Slope Covariance | -7.86 (-6.51) | ns | -5.31 (-6.08) | ** | -5.42 (-4.70) | * |
| Intercept-Slope Correlation | -0.343 | | -0.293 | | -0.296 | |
| **Fit Statistics** | | | | | | |
| $\Delta\chi^2$ | 37.8 | *** | 98.8 | *** | | |
| Change in Degrees of Freedom (Δdf) | 1 | | 1 | | | |
| RMSEA | 0.14 | | 0.1 | | 0.08 | |
| NFI | 0.99 | | 0.99 | | 0.99 | |
| CFI | 0.99 | | 0.99 | | 0.99 | |
| Hoelter | 193 (.05) | | 258 (.05) | | 444 (.05) | |
| | 333 (.01) | | 374 (.01) | | 683 (.01) | |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-19**

***Model Summary for the Conditional Growth Trajectory***

| | | |
|---|---|---|
| **Parameter Estimates** | | |
| Intercept | 47.3 (23.7)[a] | *** |
| Intercept Variance | 121.4 (22.0) | *** |
| Slope | 6.73 (19.4) | *** |
| Slope Variance | 1.77 (9.13) | *** |
| Intercept-Slope Covariance | -5.04 (-6.53) | *** |
| Intercept-Slope Correlation | -0.344 | |
| **Fit Statistics** | | |
| $\chi^2$ | 5775.7 | *** |
| Degrees of Freedom (df) | 93 | |
| RMSEA | 0.1 | |
| NFI | 0.71 | |
| CFI | 0.71 | |
| Hoelter | 119 (.05) | |
| | 130 (.01) | |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-20**

***Unstandardized and Standardized Effects for the Conditional Growth Trajectory Model***

| Conditional Model | Unstandardized | Standardized | |
|---|---|---|---|
| Gender on Intercept | -4.38 (-7.07)[a] | -0.15 | *** |
| Gender on Slope | .132 (1.22) | 0.048 | ns |
| | | | |
| African Americans (Intecept) | -12.2 (-10.3) | -0.05 | *** |
| African Americans (Slope) | -.242 (-1.16) | -0.23 | ns |
| Hispanic, Race Specified (Intercept) | -7.56 (-6.46) | 0.101 | *** |
| Hispanic, Race Specified (Slope) | .506 (2.44) | -0.14 | * |
| Hispanic, Race Not Specified (Intercept) | -9.76 (-8.46) | 0.099 | *** |
| Hispanic, Race Not Specified (Slope) | .491 (2.41) | -0.19 | * |
| Asian (Intercept) | -3.98 (-2.62) | 0.091 | * |
| Asian (Slope) | .591 (2.21) | -0.06 | * |
| Pacific Islander (Intercept) | -12.3 (-4.07) | 0.016 | *** |
| Pacific Islander (Slope) | .207 (.388) | -0.090 | ns |
| Native American (Intercept) | -8.46 (-3.16) | 0.002 | ** |
| Native American (Slope) | .025 (.053) | -0.060 | ns |
| Multiple (Intercept) | -.561 (-.268) | -0.03 | ns |
| Multiple (Slope) | -.234 (-.632) | -0.01 | ns |
| | | | |
| Middle SES (Intercept) | 7.87 (12.0) | 0.049 | *** |
| Middle SES (Slope) | .209 (1.79) | 0.433 | ns |
| High SES (Intercept) | 14.5 (19.9) | 0.074 | *** |
| High SES (Slope) | .155 (1.20) | 0.265 | ns |
| | | | |
| Diability Status (Intercept) | -4.11 (-4.22) | -0.09 | *** |
| Disability Status (Slope) | -.301 (-1.74) | -0.07 | ns |
| | | | |
| Frequency of Science (Intercept) | 1.06 (2.55) | -0.06 | * |
| Frequency of Science (Slope) | -.089 (-1.23) | -0.05 | ns |
| | | | |
| Duration of Science (Intercept) | -.344 (-.550) | -0.01 | ns |
| Duration of Science (Slope) | -.003 (-.028) | 0.001 | ns |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-21**

***Model Summary for the Modified Conditional Growth Trajectory***

| | | |
|---|---|---|
| **Parameter Estimates** | | |
| Intercept | 54.0 (32.5)[a] | *** |
| Intercept Variance | 129.0 (22.5) | *** |
| Slope | 6.92 (24.4) | *** |
| Slope Variance | 1.77 (9.13) | *** |
| Intercept-Slope Covariance | -4.84 (-6.18) | *** |
| Intercept-Slope Correlation | -0.32 | |
| **Fit Statistics** | | |
| $\chi^2$ | 758.4 | *** |
| Degrees of Freedom (df) | 38 | |
| RMSEA | 0.06 | |
| NFI | 0.95 | |
| CFI | 0.95 | |
| Hoelter | 412 (.05) | |
| | 473 (.01) | |

* $p$ < .05, ** $p$ < .01, *** $p$ < .001

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-22**

***Unstandardized and Standardized Effects for the Modified Conditional Growth Trajectory Model***

| Modified Conditional Model | Unstandardized | Standardized | |
|---|---|---|---|
| Gender on Intercept | -4.48 (-7.10) | 0.048 | *** |
| Gender on Slope | .129 (1.19) | -0.166 | ns |
| | | | |
| African Americans (Intecept) | -13.8 (-11.4) | -0.275 | *** |
| African Americans (Slope) | -.295 (-1.41) | -0.059 | ns |
| Hispanic (Intercept) | -10.9 (-12.4) | -0.300 | *** |
| Hispanic (Slope) | .434 (2.86) | 0.118 | ** |
| Asian (Intercept) | -4.86 (-3.13) | -0.076 | ** |
| Asian (Slope) | .567 (2.12) | 0.088 | * |
| Pacific Islander/Native (Intercept) | -10.8 (-5.21) | -0.126 | *** |
| Pacific Islander/Native (Slope) | .084 (.235) | 0.001 | ns |
| | | | |
| High SES (Intercept) | 7.68 (10.2) | 0.246 | *** |
| High SES (Slope) | -.042 (-.325) | -0.014 | ns |
| | | | |
| Diability Status (Intercept) | -4.41 (-4.42) | -0.108 | *** |
| Disability Status (Slope) | -.313 (-1.81) | -0.076 | ns |
| | | | |
| Frequency of Science (Intercept) | 1.03 (2.44) | 0.062 | * |
| Frequency of Science (Slope) | -.090 (-1.25) | -0.054 | ns |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-23**

***Model Comparison for the Two Conditional Growth Trajectories***

| Parameter Estimates | Conditional Model | | Modified Conditional Model | |
|---|---|---|---|---|
| Intercept | 47.3 (23.7)[a] | *** | 54.0 (32.5)[a] | *** |
| Intercept Variance | 121.4 (22.0) | *** | 129.0 (22.5) | *** |
| Slope | 6.73 (19.4) | *** | 6.92 (24.4) | *** |
| Slope Variance | 1.77 (9.13) | *** | 1.77 (9.13) | *** |
| Intercept-Slope Covariance | -5.04 (-6.53) | *** | -4.84 (-6.18) | *** |
| Intercept-Slope Correlation | -0.344 | | -0.32 | |
| **Fit Statistics** | | | | |
| $\Delta\chi^2$ | 5017.3 | *** | | |
| Change in Degrees of Freedom (Δdf) | 55 | | | |
| RMSEA | 0.1 | | 0.06 | |
| NFI | 0.71 | | 0.95 | |
| CFI | 0.71 | | 0.95 | |
| Hoelter | 119 (.05) | | 412 (.05) | |
| | 130 (.01) | | 473 (.01) | |

* $p$ < .05, ** $p$ < .01, *** $p$ < .001

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

**Table 4-24**

***Model Summary for the Linear Model of 8th Grade Interest and Engagement in Science***

| | Regression Weights | | |
|---|---|---|---|
| | Unstandardized | | Standardized |
| Intercept | 3.03 (14.1)[a] | *** | |
| Gender | .161 (2.35) | ** | 0.080 |
| African Americans | -.504 (-3.68) | *** | -0.132 |
| Hispanics | -.386 (-3.76) | *** | -0.138 |
| Asians | .223 (1.26) | ns | 0.045 |
| Pacific Islanders/Native Americans | -.395 (-1.70) | * | -0.060 |
| SES | .483 (5.91) | *** | 0.210 |
| Disability Status | -.592 (-5.56) | *** | -0.196 |
| Frequency of Science in 3rd Grade | .003 (.063) | ns | 0.002 |
| Duration of Science in 3rd Grade | .011 (.156) | ns | 0.006 |

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] DEFT Corrected Critical ratio (CR: statistic/standard error) is in parenthesis.

***Figure 4-1. Mean Science IRT Scale Scores, No Factors Included***

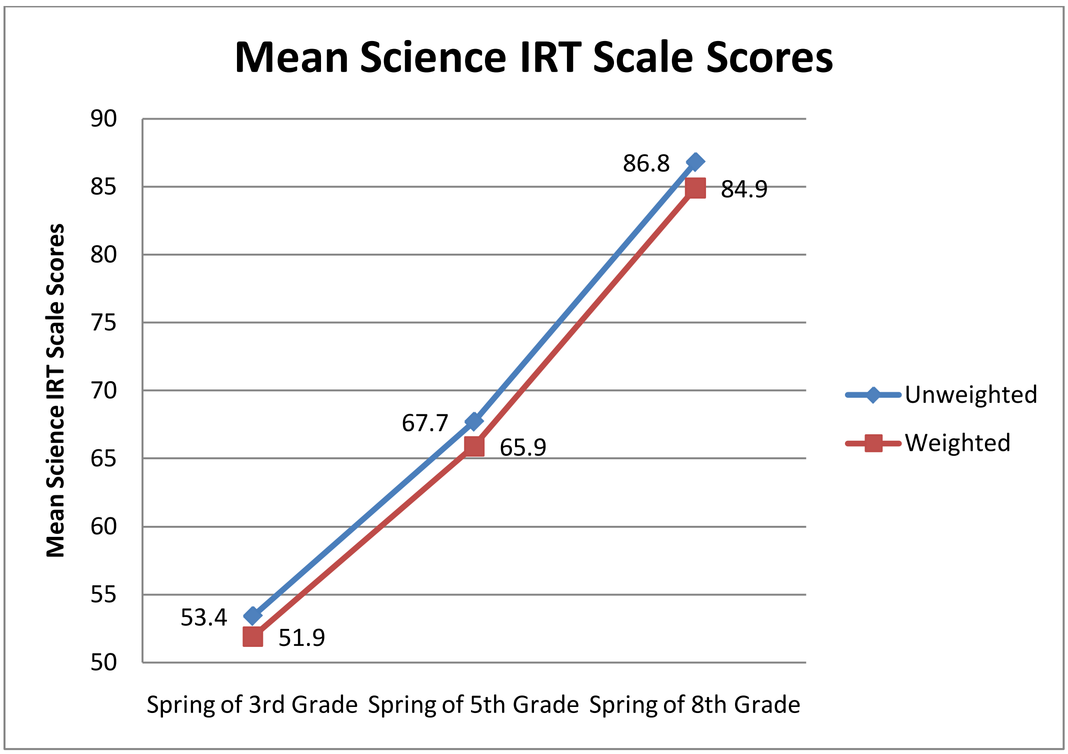


***Figure 4-2. Weighted Mean Science IRT Scale Scores by Gender Compared with Overall Weighted Scores.***

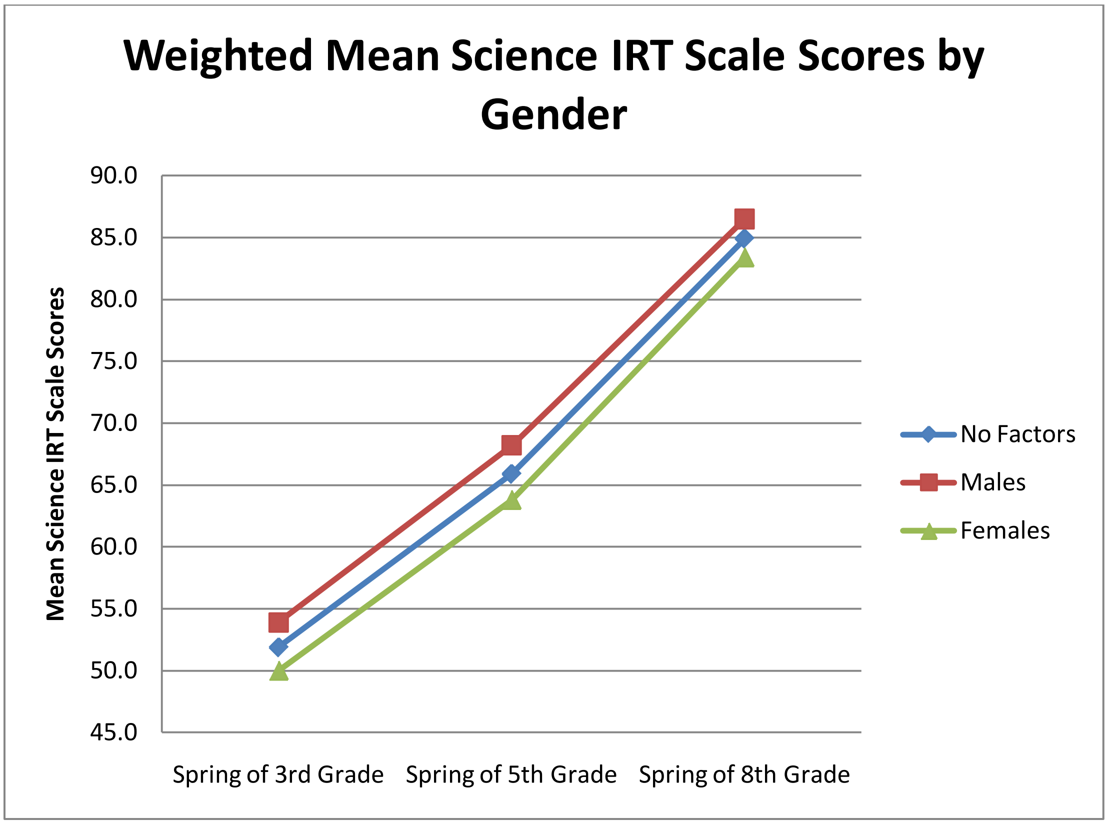


***Figure 4-3. Weighted Mean Science IRT Scale Scores by Race and Ethnicity Compared with Overall Weighted Scores***

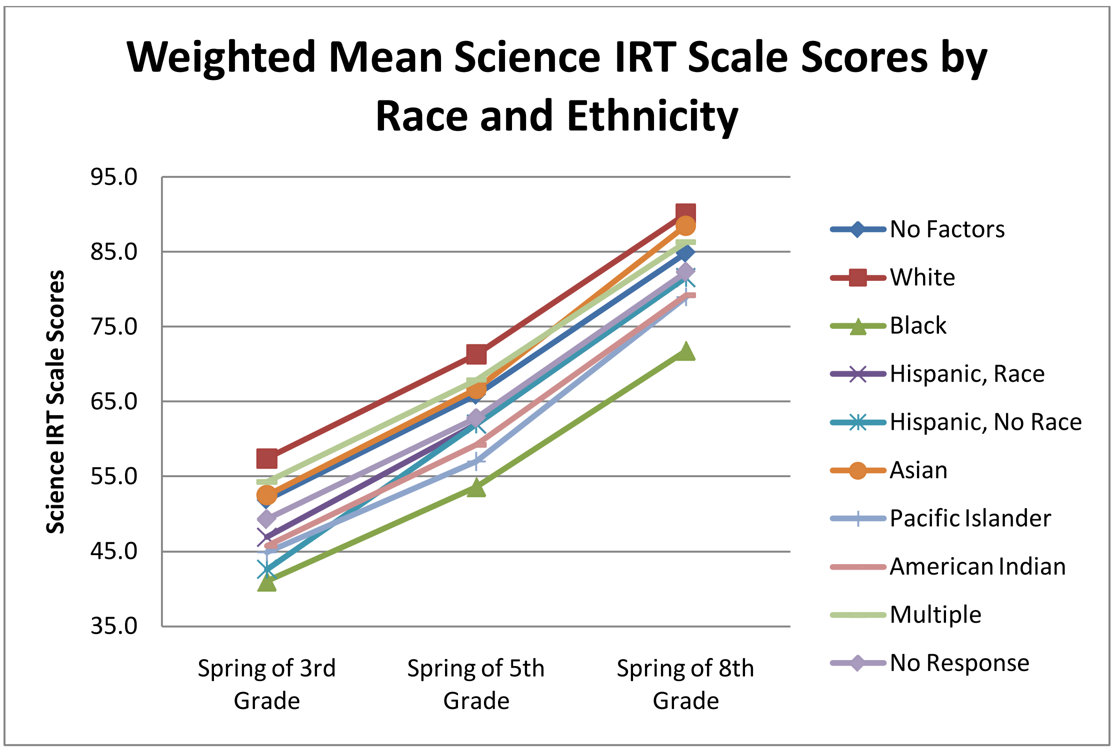


***Figure 4-4. Weighted Mean Science IRT Scale Scores by SES Compared with Overall Weighted Scores***

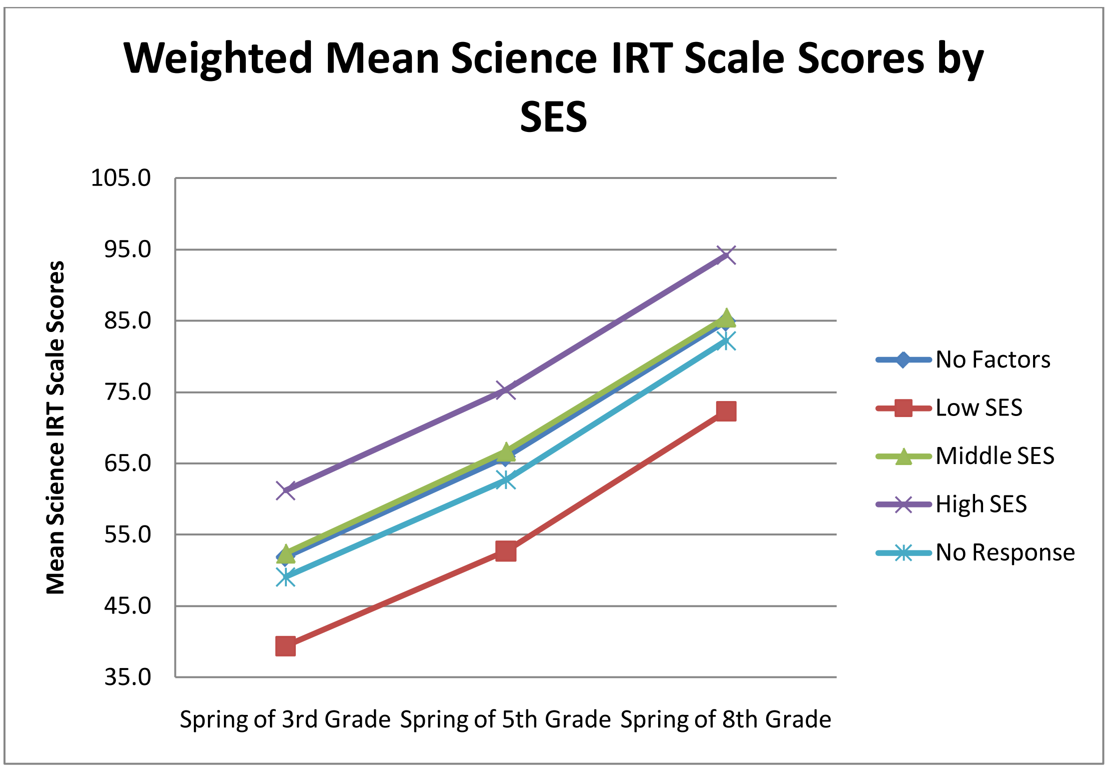


***Figure 4-5. Weighted Mean Science IRT Scale Scores by Disability Status Compared with Overall Weighted Scores***

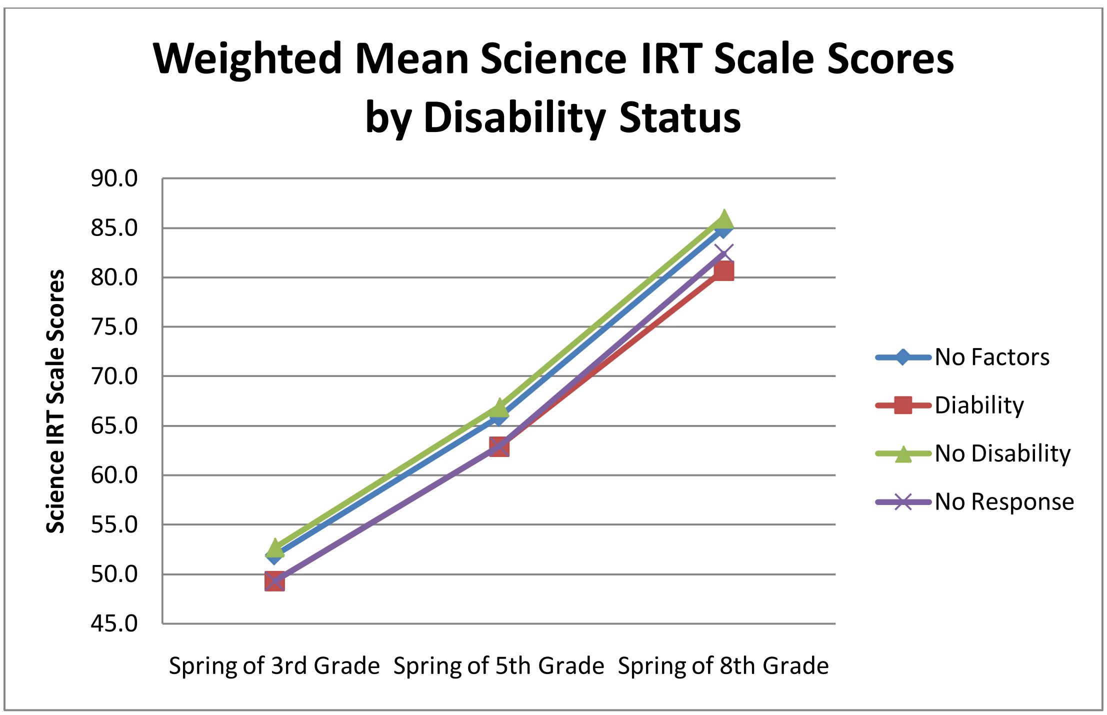


***Figure 4-6. Percentage Distribution of Teacher Responses to How Often Children Work on Science in Third Grade***

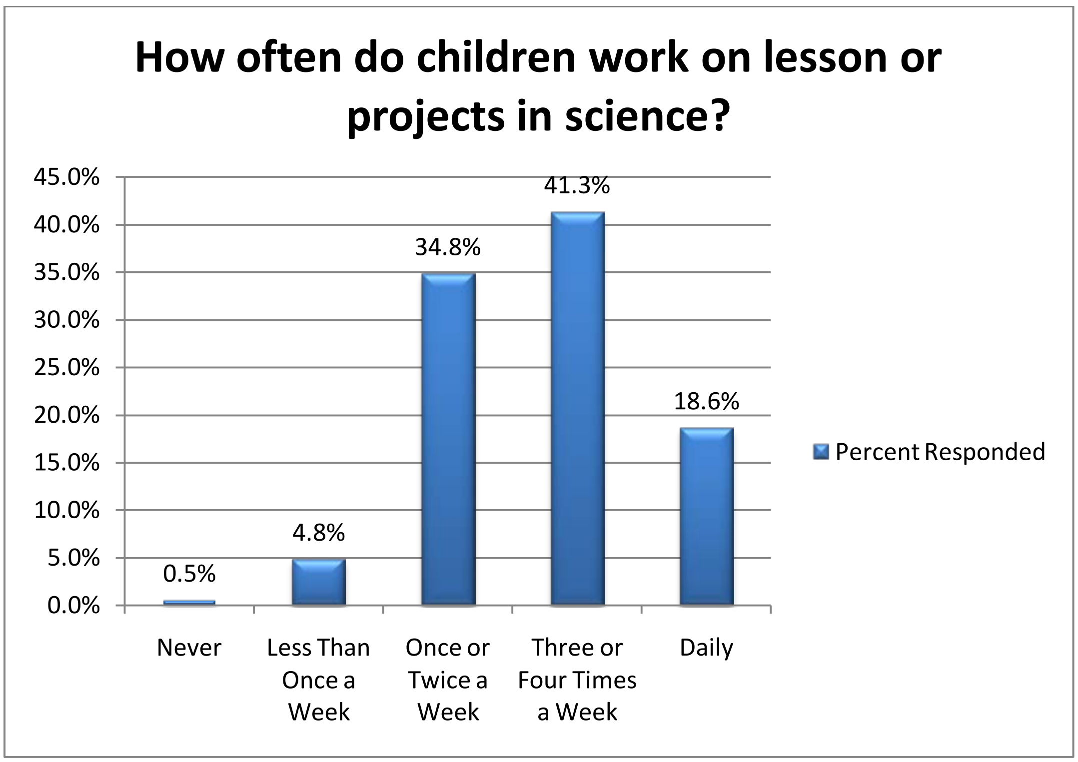


***Figure 4-7. Percentage Distribution of Teacher Responses to How Much Children Work on Science in Third Grade***

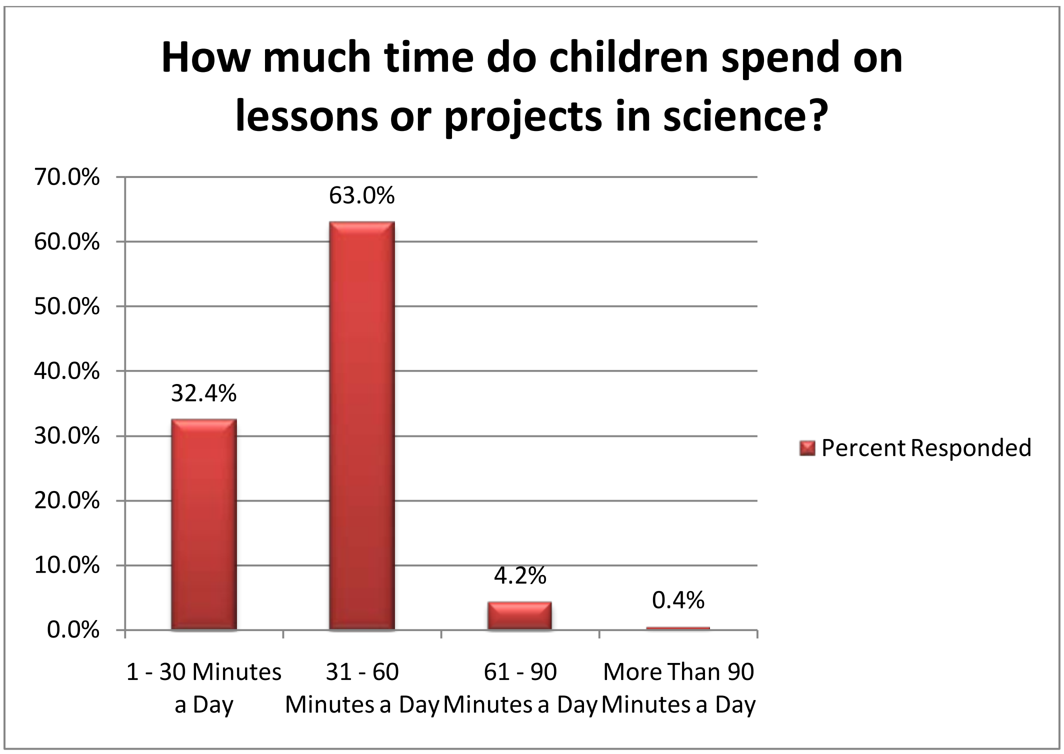


***Figure 4-8. Weighted Mean ARS Scores by Gender Compared with Overall Weighted Scores***

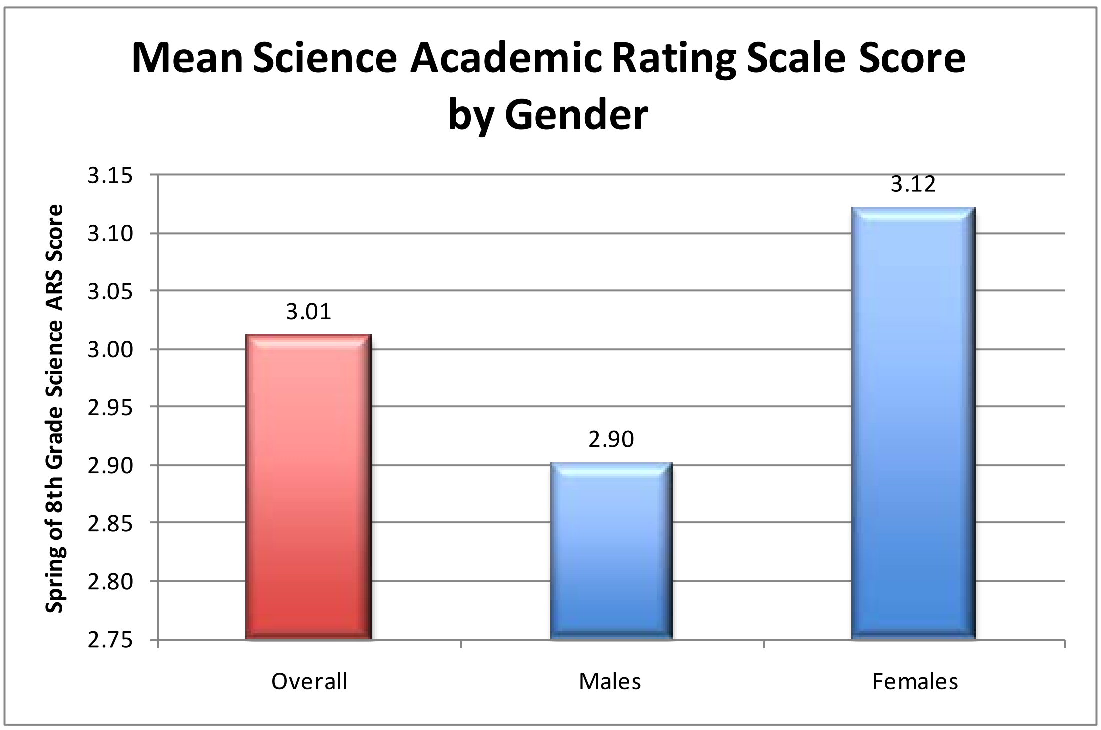


***Figure 4-9. Weighted Mean Science IRT Scale Scores by Race and Ethnicity Compared with Overall Weighted Scores***

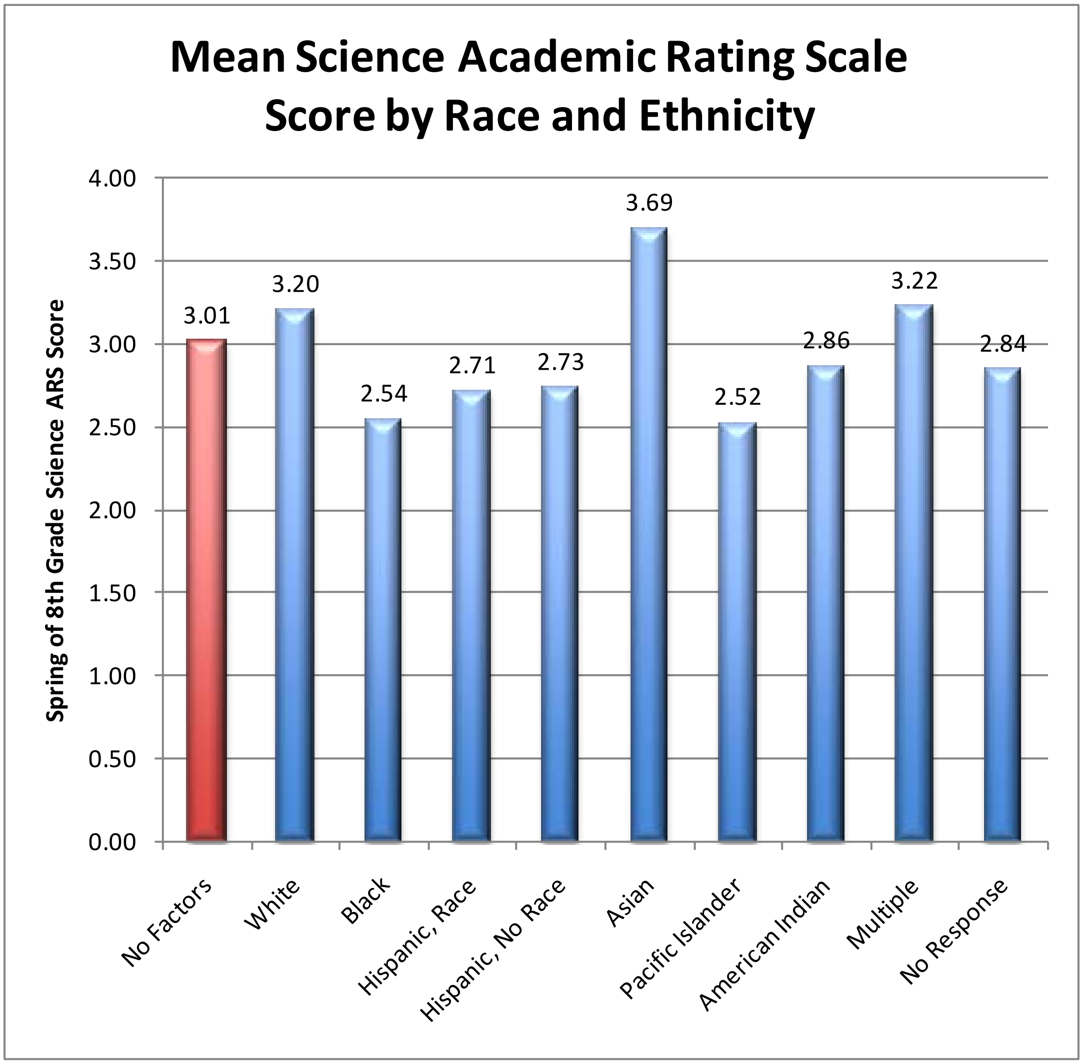


***Figure 4-10. Weighted Mean Science IRT Scale Scores by SES Compared with Overall Weighted Scores***

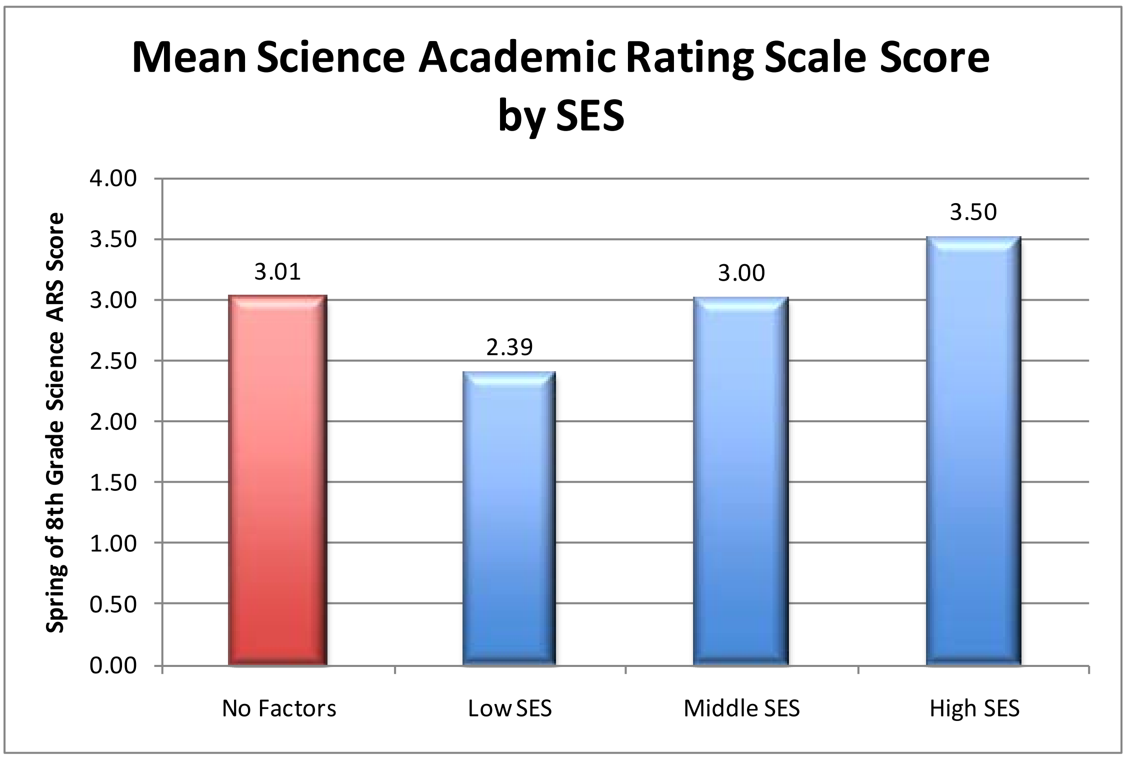


***Figure 4-11. Weighted Mean Science IRT Scale Scores by Disability Status Compared with Overall Weighted Scores***

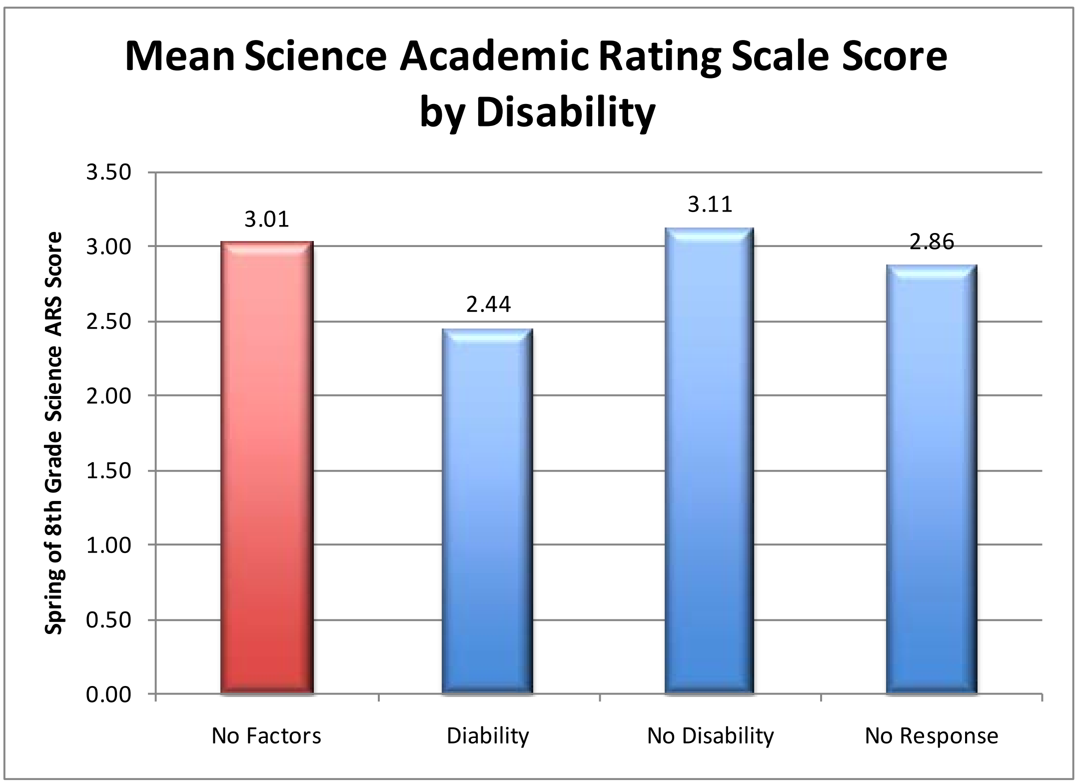


*Figure 4-12. Unconditional Linear Model of Science Achievement with the Assumption of Unequal Residual Variances (Heteroscedastic Errors)*

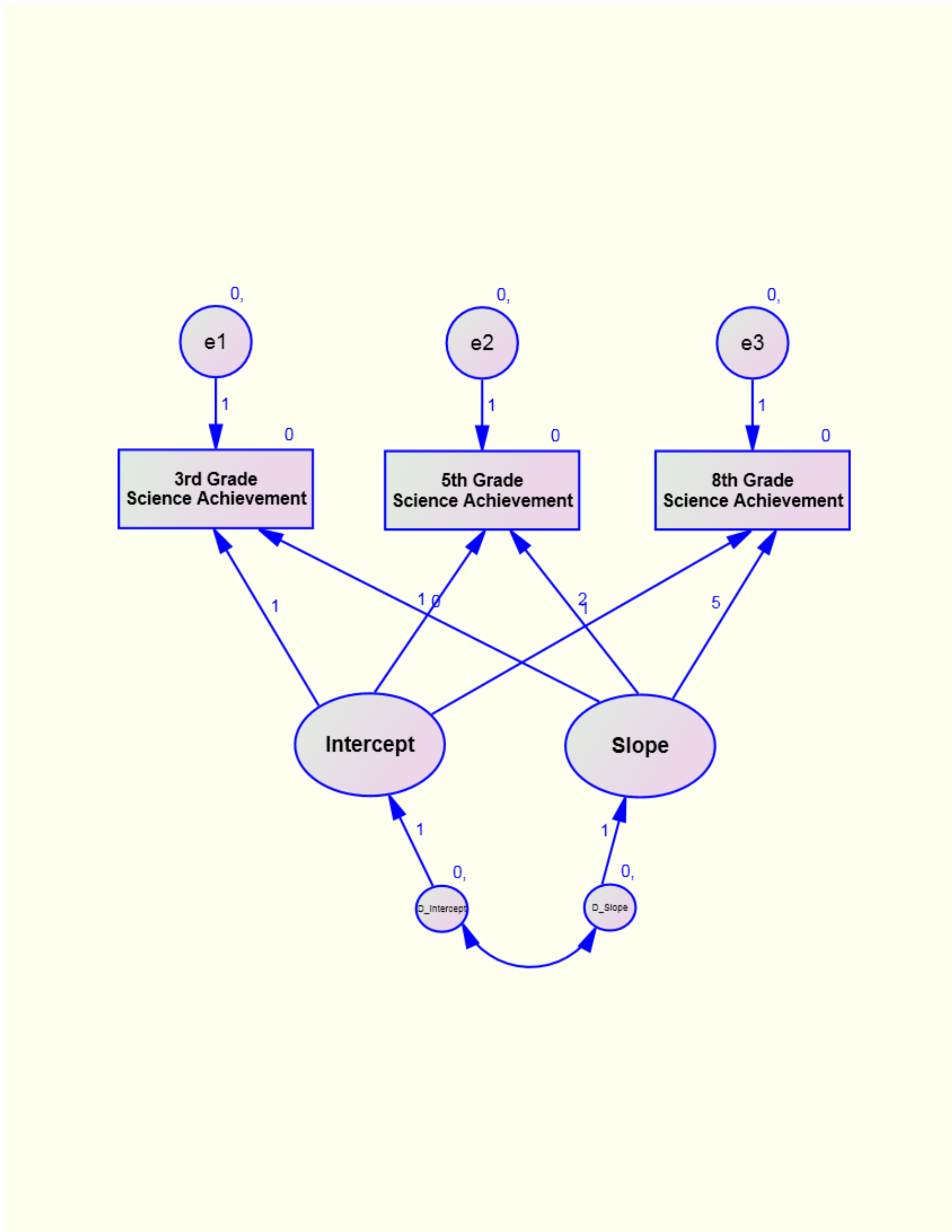


***Figure 4-13. Unconditional Linear Model of Science Achievement with the Imposed Condition of Equal Residual Variances (Homoscedastic Errors)***

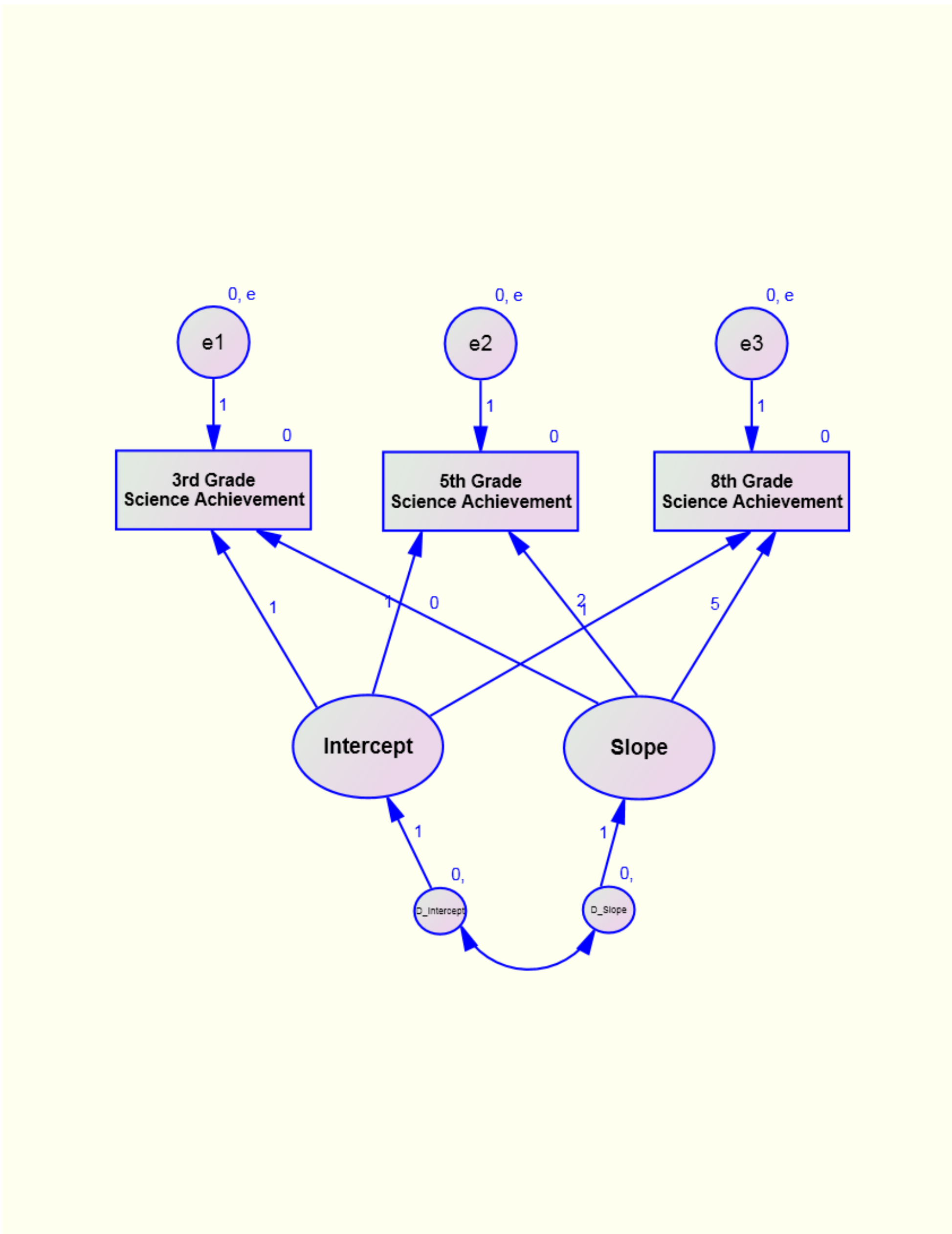


***Figure 4-14. Unconditional Spline Model of Science Achievement with the Imposed Condition of Equal Residual Variances (Homoscedastic Errors)***

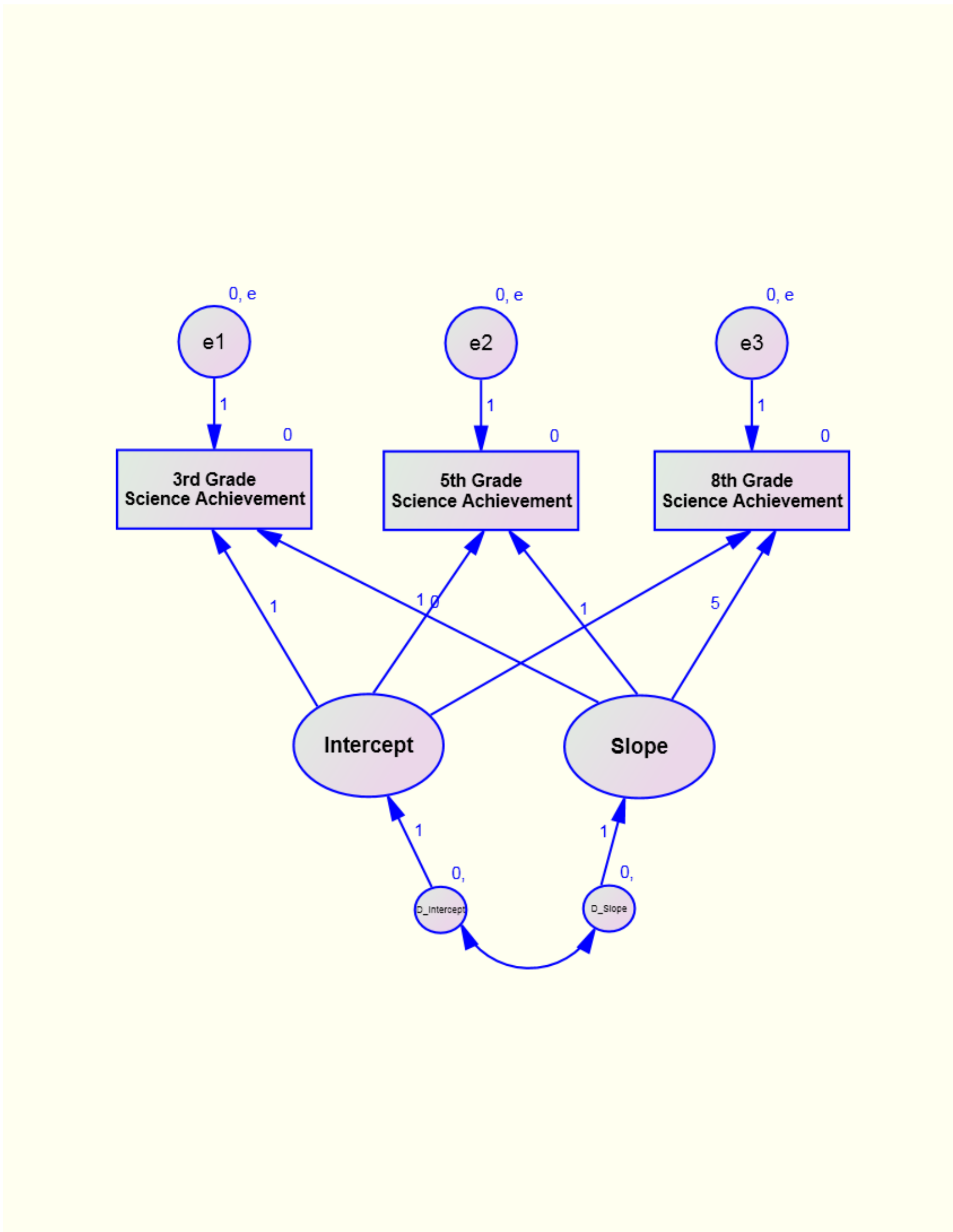


***Figure 4-15. Conditional Model of Science Achievement with Control Variables and Predictor Variables***

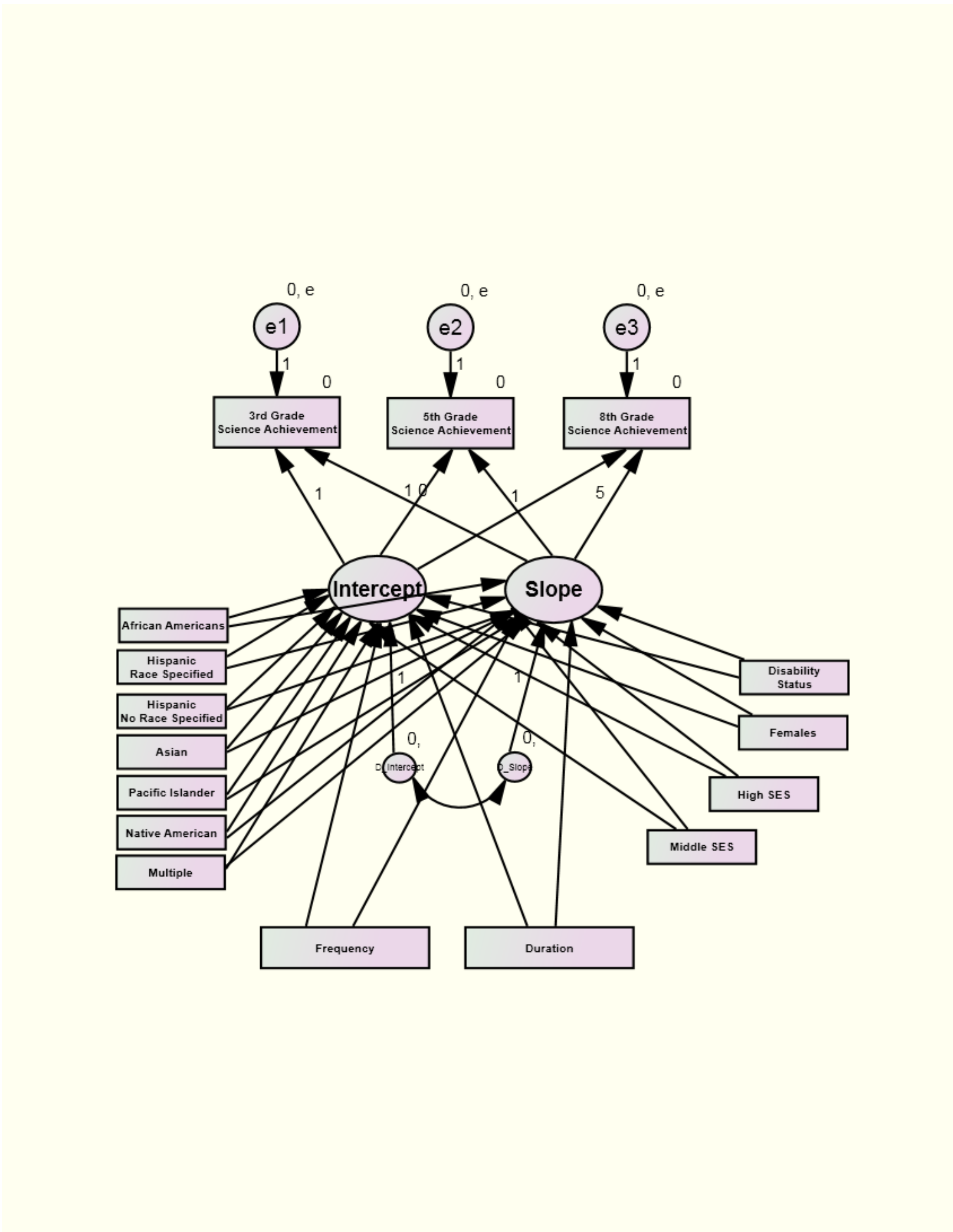


***Figure 4-16. Modified Conditional Model of Science Achievement with Control Variables and Predictor Variables***

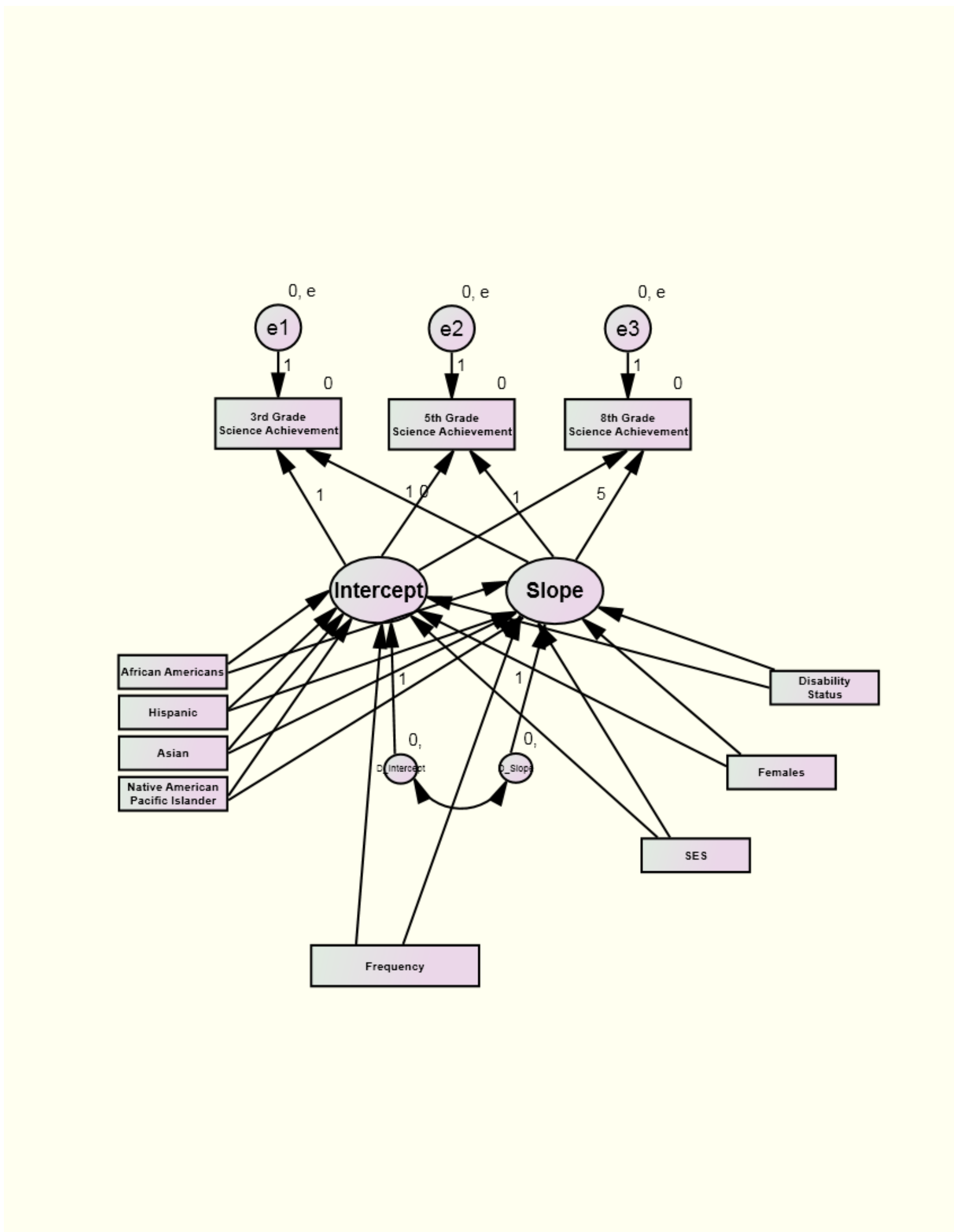
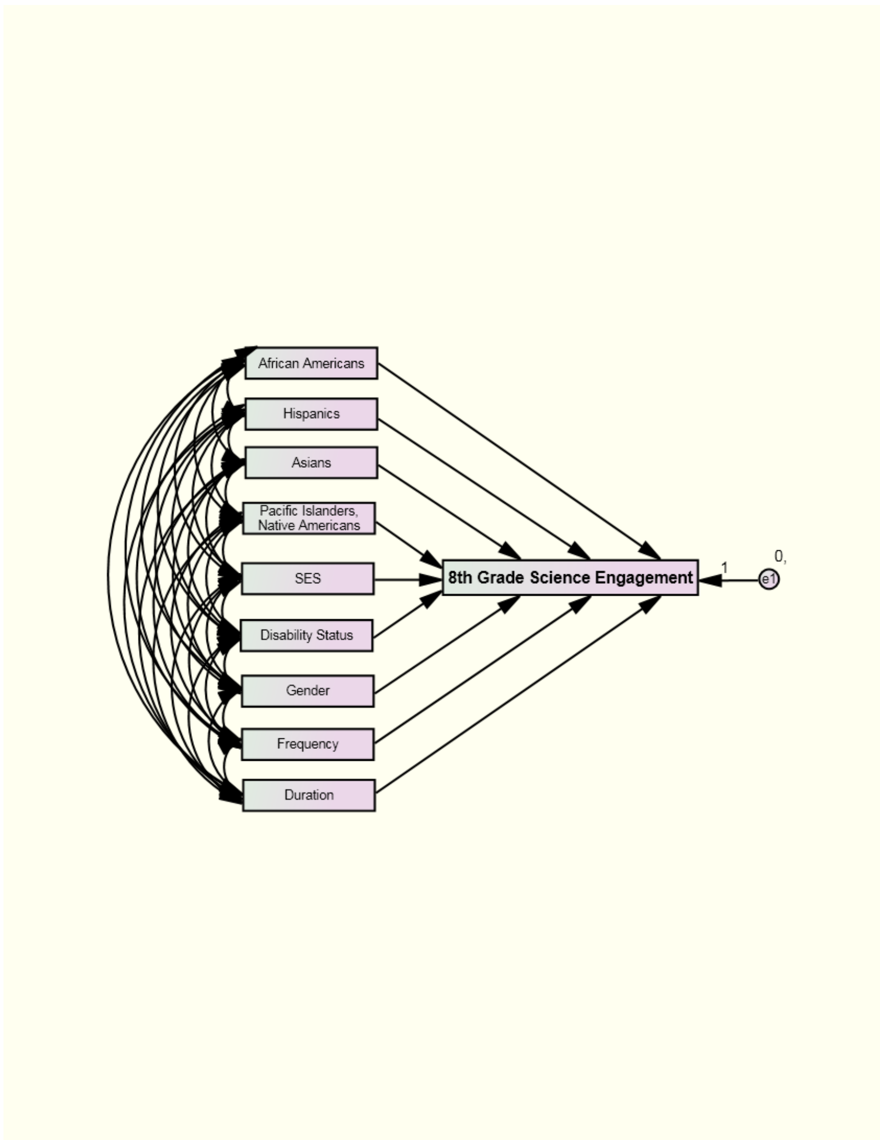


***Figure 4-17. Linear Interest and Engagement Model***



# CHAPTER 5

# DISCUSSION AND IMPLICATIONS

The overall focus of this analysis was to investigate the trajectory of science achievement from the spring of their third grade year to the spring of their eighth grade for first-time kindergarteners participating in the ECLS-K study. The specific questions associated with this study sought to describe the general pattern of science achievement, the role frequency and duration of science in the third grade played in the gains made by these first-time kindergarteners, and how the frequency and duration of science in the third grade was associated with students' interest in eighth grade science. To address each of these questions, three analyses were performed using the ECLS-K data set for the 1998-1999 kindergarten cohort. After a thorough descriptive analysis of the outcome, control, and predictor variables, an unconditional latent growth model was developed using the three science IRT scale scores. After a growth pattern of science achievement was determined, a conditional growth model was used to evaluate the influence of the control and predictor variables (i.e., frequency and duration of science in the third grade) on the trajectory of science achievement. The last analysis utilized a linear model to evaluate the association of frequency and duration of science in the third grade on later interest in eighth grade science.

The strength of this study lies in the longitudinal investigation of science achievement using a large-scale, nationally representative data set. It contributed to the overall picture of the progression of science achievement in the early stages of science education and allowed for the investigation of earlier events and decisions associated with achievement and interest in subsequent years. In light of the recent attention placed on the United States' science proficiency relative to the rest of the World, this study looked at science achievement using longitudinal, not cross-sectional data. *The Nation's Report Card. Science 2009* (NCES, 2011) reported that 34 percent of fourth graders, 30 percent of eighth graders, and 21 percent of 12$^{th}$ graders demonstrated proficiency in science. At first glance, these results seem to stand in direct contradiction to the results of this study, mainly that students demonstrated non-linear growth in science achievement between the spring of third grade and spring of eighth grade. However, the data analyzed from the National Assessment of Educational Progress, or NAEP, is cross-sectional and cannot be interpreted in terms of growth. Thus, the results of this study provide a different perspective of science learning in that it studies the progression of achievement demonstrated by a cohort of students in America's classrooms.

This study incorporated both the research on early interest development in science, the importance of early experiences in science, and the nature of science achievement within the United States. The focus on the amount of exposure students have to science experiences in the elementary school and student science achievement may provide useful information on the time devoted to science at an age and time period that research suggests is extremely important in the development of interest. Furthermore, the emphasis on longer-range outcomes associated with the amount of science in elementary school will potentially help clarify the breadth of these early experiences. What follows is a discussion of the results from each component of the analysis and the potential implications of the study. This chapter concludes with a series of recommendations based on outcomes of the study and a discussion of the study's limitations.

## Descriptive Analysis

The descriptive analysis provided the general picture for each outcome variable independently and across each of the control variables of gender, race and ethnicity, SES, and disability status. For example, what is the basic pattern of mean science IRT scale scores across the three years of assessment? What does this pattern look like for African American boys as compared to white males? Similarly, is there a visual difference in the mean growth pattern for students with a reported disability compared with those not reporting a disability? The same general questions guided the descriptive analysis of the science ARS scores across the various control variables. With regard to the predictor variables of frequency and duration of science in the third grade, the descriptive analysis provided information about the range of answers and responses provided by teachers about the time allocated for science.

The mean science IRT scale scores appeared to “grow” over the three years explored in this study. The basic pattern resembles a linear pattern with some variation during the spring of fifth grade. The outcomes from this descriptive analysis across the control variables suggested that there was a difference in the average growth pattern of science achievement between many of the subgroups. For example, girls appeared to differ from boys, African Americans differed from Asians, low SES students differed from high SES students, and those with a disability were different from those without a disability. Although this may come as no surprise, what was interesting about the descriptive analysis was that the average differences did not disappear across the three assessments suggesting that the gap in science IRT scale scores present during the spring of third grade did not close by the spring of eighth grade. Similarly, there was a noticeable difference in science ARS scores across gender, race and ethnicity, SES, and disability status.

The descriptive analysis hinted at the presence of a substantive difference in growth patterns and eighth grade science interest. However, the intent of this analysis was purely descriptive and does not begin to provide any indication of why or whether a statistically significant effect, association, or influence exists between the control variables and the growth trajectory or eighth grade science interest. This was reserved for the growth curve analysis of science achievement.

## Science Achievement Growth Curve Analysis

The unconditional growth curve analysis identified the specific growth pattern associated with science IRT scale scores that represent science achievement from the spring of third grade to the spring of eighth grade. The development of the unconditional model evaluated the growth trajectory in the absence of any control or predictor variables and determined if a significant amount of individual variation exists around the initial starting point of science achievement and the growth rate across the three assessments. Put differently, this model evaluated the nature of the growth curve as well as how much individuals differ in their growth trajectories. The results of the unconditional model indicated that the growth pattern across these repeated measures was non-linear and that significant individual variation existed in the initial starting point and the growth rate in science achievement. This means that, on average, individuals “grew” in science achievement in a non-linear path and that individual differences exist around the trajectories of the students in this study.

An additional result from the unconditional model described the relationship between the starting point and the growth rate in science IRT scale scores. This relationship was found to be negative. Given that there is significant variation in individual trajectories, a negative relationship between the starting point and the growth rate implies that students starting out with higher science achievement grow at a slower rate than those students starting out with lower science achievement.

Four implications or “take-home messages” can be extracted from these results and are best thought about within the context of an elementary school classroom. The first-time kindergarteners in this study, in general, experienced growth in science achievement from the spring of their third grade year to the spring of their eighth grade year. The growth pattern modeled in this study is reassuring in light of the recent attention on science achievement within the United States (i.e., NSB, 2010; Marx & Harris, 2006; NAS, 2005). Thus, the first implication is that students appeared to show gains in science as they move from grades three through eight in their respective public schools. Although this result does not speak to the rate of achievement growth relative to the rest of the World, it does speak to the growth of the public school students in this study.

Growth in science achievement followed a non-linear trajectory implying that the gains made between school years were not consistent. Students exhibited greater gains in some years and lesser gains in other years. This second implication prompts the question of why. Why are student gains non-linear? Why do students exhibit greater gains in some years and lesser gains in others? These questions are causal in nature and extend beyond the focus of this study. However, more work is needed to investigate what factors contribute to greater gains in achievement.

Third, there is a significant difference in the individual growth trajectories across the first-time kindergarteners in this study. The trajectory of science achievement most likely varies from student to student. A logical next step would be to determine what factors account for this individual variation. Two possible factors that may account for this individual variation in growth trajectories was the focus of the second research question and was addressed with a conditional growth curve model.

The final implication spawns from the negative relationship between the initial starting point and growth rate. What this seems to imply is that students that start out with lower achievement in science demonstrate a higher growth rate than those with higher initial achievement. Put differently, students with lower initial achievement appear to “catch-up” or make gains at a more rapid rate. How much is the “catch-up” and what are the mechanisms and causes of this “catch-up” are not directly addressed in the analyses. However, it is an extremely encouraging outcome of this study to find that this “catch-up” exists.

As highlighted previously, one important outcome of the unconditional model was the significant difference in the individual growth trajectories in science achievement across first-time kindergarteners, implying that the trajectory of science achievement for one student will more than likely look different than the trajectory of a second student. The conditional model was developed to directly address this individual variation and evaluate potential factors associated with this individual variation. Using the predictor variables of frequency and duration of science in the third grade, a significant amount of individual variation in science achievement growth trajectories was accounted for by the frequency of science in the third grade but not the duration of science. More specifically, those students that were offered science in the third grade more frequently demonstrated higher initial achievement levels than those students offered science less frequently in the third grade. However, what is also interesting is that the growth rate of those students did not differ significantly. Practically speaking, students with more exposures to science in grade three started out with high achievement levels, but did not grow at a faster rate than those with fewer exposures to science. Thus, the advantage gained from the more frequent exposures persisted through the spring of eighth grade.  Taken a step further, the gains in science achievement appear to be dependent on the student's exposure to science and not their ability to learn science.  Stated differently, students with more frequent exposure to science in third grade had an initial advantage, but did not make gains at a rate different from those that had less exposure to science in third grade.  This outcome is in line with research supporting early experiences in science (Driver et al., 1994; Fleer & Robbins, 2003b; Stein & McRobbie, 1997; French, 2004; Gelman & Brenneman, 2004; Tytler & Peterson; 2003).  Early and frequent exposure was beneficial to the science achievement of the students in this study.

On the other hand, the duration of science (i.e., how long each exposure lasted) did not produce a significant effect on the individual growth trajectories in science.  The duration of exposure to science was not as important as the frequency of exposures to science.

Although the variables for gender, race and ethnicity, SES, and disability status were included in the model for purposes of control, the effects of these variables on the individual science trajectory tell an interesting story that is worth discussing.  The demographic variables included in the model account for a significant portion of the individual variance in growth trajectories.  In and of itself, this is not surprising.  Much of the literature presented in the second chapter of this study suggests that demographic differences exist in science experiences (Brotman & Moore, 2008; Scantlebury & Baker, 2007; Lee & Buxton, 2008; Aikenhead, 2001; Cuevas et al., 2005).  However, results from this study indicated that these variables accounted for the variance in the initial starting points of science achievement but the growth rates of each subgroup were not statistically different.  For example, females indicated a lower initial starting point in science achievement than males.  Yet, females grew at the same rate as males in regard to science achievement.  This same pattern existed for African Americans, Pacific Islanders/Native Americans when compared to white students, students with high SES when compared with low SES, and students with disabilities when compared to students without disabilities. Put quite frankly, African American children made gains in science at the same rate as white children, but didn't start out at the same spot. Furthermore, the relationship between initial starting points and growth rates was again negative suggesting the possibility of "catching-up". The science achievement gap pointed out in the literature (e.g., Brotman & Moore, 2008; Baker, 1998; Andre et al., 1999; Beghetto, 2007; Cuevas et al., 2005; Judge, Puckett, & Cabuke, 2004) may be a product of the initial starting points and the inability of certain demographics to catch-up within the K-12 school years. The persistence in the achievement gap might be because there is not enough time, even though catch-up is occurring, to overcome the initial gap in science achievement.

A different pattern existed for Hispanics and Asians in that they have a significantly higher growth rate than white children. When compared with white children, these two demographic groups had lower initial starting points in science achievement, but had significantly higher growth rates. This would seem to reduce and eliminate any achievement gap in science achievement for these two demographic subgroups.

The implications from this analysis seem to favor more early intervention programs, especially those focused on underrepresented minorities. Yes, the frequency of exposure to science in the third grade benefited the first time kindergarteners initial starting points in science achievement. The growth rate was not associated with the frequency of science exposures. Thus, a reduction in the frequency of science may influence achievement growth well beyond a single year of schooling. More exposure to science early on in the educational careers of students may provide an important jump-start to their achievement. That is, they will start out higher on the trajectory than those students deprived of frequent exposure to science. Given that the growth rates do not differ significantly, the advantages of frequent exposures to science continue beyond a single year. This is also in line with the literature on the importance of early experiences in science (Driver et al., 1994; Gleer & Robbins, 2003; Stein & McRobbie, 1997; Tytler & Peterson, 2003; Gelman & Brenneman, 2004; French, 2004) and their importance in developing scientific knowledge. The importance of more frequent science, earlier in school is even more important for underrepresented minorities.

## Linear Model of Science Interest Analysis

The linear model demonstrated that there was no association between frequency and duration of science in the third grade and subsequent interest in eighth grade science. Thus, the amount of science opportunities and experiences in the third grade seemed to play no significant role in the level of interest and engagement in eighth grade science. What the model did demonstrate was that gender, race and ethnicity, SES, and disability status were significant predictors in the level of interest eighth grade science as measured by the science ARS. Females indicated higher levels of interest, as did those students from high SES backgrounds. On the other hand, African Americans, Hispanics, and students with a disability demonstrated lower levels of interest in eighth grade science.

The mechanism and cause of this variance in levels of engagement across the various subgroups is unclear from this analysis. However, the results are interesting in that the differences across demographic subgroups point towards a continued gap in science education, only this time in regard to interest in the eighth grade.

## Recommendations from the Study

Taking a step back from the four separate but interrelated analyses, this study provided insights into the “big picture” of early science achievement and later interest. From these insights, several recommendations for elementary science education are presented below and are both justified and worth considering in light of the results of this study.

> ***Recommendation #1:*** *Increased attention and resources should be devoted to early science exposure and experiences. The quality and quantity of science learning in elementary school including Pre-K, kindergarten, first, and second grade classrooms is important to the achievement of all students in science.*
>
> ***Recommendation #2:*** *Early intervention programs should be designed to provide access to science experiences for underrepresented minorities.*
>
> ***Recommendation #3:*** *Early elementary school students should have frequent exposure to science experiences. Compacting science into rotation cycles with other disciplines may not be an effective practice for improving science achievement.*
>
> ***Recommendation #4:*** *Continued focus through intervention programs and further research on the levels of engagement and interest exhibited by underrepresented minorities in science is necessary.*

These recommendations take into account each analysis independently as well as the four analyses as a whole. Each recommendation serves an additional purpose of providing a direction for future research. If someone were to ask what comes next, these recommendations point to areas that need further research and more investigation into the effects, association, and interactions of achievement, interest, and science class.

When formulating these recommendations, consideration was given to the limitations of the data set, statistical procedures, and the ability to generalize the results to the entire elementary school population in the United States. A discussion of these limitations is articulated in the final section of this chapter.

## Limitations of the Study

Every study has its limitations and this one is no different. Careful consideration has been given to each of the following limitations through methodological decisions as well as the adjustment of analytic procedures. However, some limitations cannot be avoided simply because, in the words of Robert Tai, education research studies children, not electrons. Thus, researchers must accept all that comes with studying children.

The first limitation deals with the study sample. The initial wave of data collection administered by the NCES was nationally representative of all kindergarteners enrolled in the 1998-1999 school year. Thus, analyses performed using the first wave of data is potentially generalizable to all children enrolled in kindergarten during the 1998-1999 school year. Due to attrition, subsequent waves of data collection are not nationally representative, but are representative of the original ECLS-K cohort (i.e., those students in the original wave of data collection). As a result, the sample of students analyzed in this specific study is representative of the cohort and not national representative of all third, fifth, and eighth grades nationally. Careful attention has been given to each statement in the discussion section to not over generalize the results. The large sample size analyzed for the first two components of the analysis (*n* = 5,854) along with the very well designed ECLS-K study makes the results of this analysis robust. However, it may not be generalizable to every third, fifth, and eighth grades nationally.

A second limitation deals with the eighth grade science ARS score. Not every student has a science ARS score for eighth grade. As described in the methodology, fifty percent of the eighth graders were randomly selected to receive a science ARS score while the remaining fifty percent received a math ARS score. Thus, the sample size for third component of the analysis was reduced to 2,743. The same impact on generalizability from the first limitation applies here as well.

A final limitation is going to be addressed by the NCES through the new ECLS-K cohort, which began this year. This new cohort will collect data every year and gather information about the four core areas at each wave of data collection. For this study, the science achievement data was only available for the fifth, sixth, and seventh wave of data collection during grades three, five, and eight. In addition, there is no data collection for grades four, six, and seven in the 1998-1999 cohort. This limitation is unavoidable, but worth mentioning. This limitation alone opens the door for future work in this area.

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# APPENDICES

## APPENDIX A: *SPSS* syntax for data processing

# APPENDIX A:

# SPSS SYNTAX FOR DATA PROCESSING

```
* SPSS program to create extract file

FILE HANDLE FHAND /NAME='F:\childk8p.dat' /LRECL=5310.
DATA LIST FILE=FHAND FIXED RECORDS = 15 TABLE
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  GENDER 377-378
  RACE 379-380
  R3SAMPLE 400-400
  FKCHGSCH 423-424
  R4R2SCHG 427-428
  R5R4SCHG 433-434
  R6R5SCHG 435-436
  R7R6SCHG 437-438
  C567CW0 861-867  (2)
  C7CPTS0 959-965  (2)
  C5R2SSCL 2086-2091  (2)
  C6R2SSCL 2340-2345  (2)
  C7R2SSCL 2598-2603  (2)
  T5ARSSCI 2867-2871  (2)
  T6ARSSCI 2917-2921  (2)
  T7ARSSCI 2967-2971  (2)
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  P7DISABL 3937-3938
  W8RACETH 3989-3990
  W8SESQ5 4024-4024
  T5GLVL 4206-4207
  T6GLVL 4208-4209
  T7GLVL 4210-4211
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  C1ASMTYY 4481-4484
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  A5TXSCI 2886-2887
  J61OFTSC 5079-5080
  J61TXSCI 5097-5098
/5
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/13
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  C7CPTS88 57-64  (2)
  C7CPTS89 65-72  (2)
  C7CPTS90 73-80  (2)
    .

  VARIABLE LABEL
    CHILDID       "CHILD IDENTIFICATION NUMBER"
    GENDER       "CHILD COMPOSITE GENDER"
    RACE       "CHILD COMPOSITE RACE"
    R3SAMPLE       "R3 CHILD SUBSAMPLED IN ROUND 3"
    FKCHGSCH       "FK CHD CHANGED SCHLS BETWEEN ROUND 1 & 2"
    R4R2SCHG       "R4 CHILD SCH CHANGE TYPE BTWN RNDS 2 & 4"
    R5R4SCHG       "R5 CHILD SCH CHANGE TYPE BTWN RNDS 4 & 5"
    R6R5SCHG       "R6 CHILD SCH CHANGE TYPE BTWN RNDS 5 & 6"
    R7R6SCHG       "R7 CHILD SCH CHANGE TYPE BTWN RNDS 6 & 7"
    C567CW0       "C5C6C7 CHILD PANEL WEIGHT FULL SAMPLE"
    C7CPTS0       "C7 CHILD-PARENT-TCHR(S) WEIGHT FULL SAMP"
    C5R2SSCL       "C5 RC2 SCIENCE IRT SCALE SCORE"
    C6R2SSCL       "C6 RC2 SCIENCE IRT SCALE SCORE"
```

C7R2SSCL "C7 RC2 SCIENCE IRT SCALE SCORE"
T5ARSSCI "T5 SCIENCE ARS SCORE"
T6ARSSCI "T6 SCIENCE ARS SCORE"
T7ARSSCI "T7 SCIENCE ARS SCORE"
P1FIRKDG "P1 FIRST-TIME KINDERGARTENER"
P7DISABL "P7 CHILD W/ DISABILITY"
W8RACETH "W8 CHILD RACE- COMPOSITE"
W8SESQ5 "W8 CATEGORICAL SES MEASURE"
T5GLVL "T5 GRADE LEVEL OF CHILD"
T6GLVL "T6 GRADE LEVEL OF CHILD"
T7GLVL "T7 GRADE LEVEL OF CHILD"
C1ASMTMM "C1 ASSESSMENT MONTH"
C1ASMTDD "C1 ASSESSMENT DAY"
C1ASMTYY "C1 ASSESSMENT YEAR"
A5OFTSCI "A5 Q26D HOW OFTEN SCIENCE"
A5TXSCI "A5 Q26D TIME FOR SCIENCE"
J61OFTSC "J61 Q1E1 HOW OFTEN SCIENCE"
J61TXSCI "J61 Q1E2 TIME FOR SCIENCE"
N7LIFESC "N7 Q18A PERCENT TIME ON LIFE SCIENCE"
N7EARSC "N7 Q18D PERCENT TIME ON EARTH SCIENCE"
N7ENVRSC "N7 Q18E PERCENT TIME ON ENVIRON SCIENCE"
N7OTHSC "N7 Q18F PERCENT TIME ON OTHER SCIENCE"
C567CW1 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 1"
C567CW2 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 2"
C567CW3 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 3"
C567CW4 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 4"
C567CW5 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 5"
C567CW6 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 6"
C567CW7 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 7"
C567CW8 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 8"
C567CW9 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 9"
C567CW10 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 10"
C567CW11 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 11"
C567CW12 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 12"
C567CW13 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 13"
C567CW14 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 14"
C567CW15 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 15"
C567CW16 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 16"
C567CW17 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 17"
C567CW18 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 18"
C567CW19 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 19"
C567CW20 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 20"
C567CW21 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 21"
C567CW22 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 22"
C567CW23 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 23"
C567CW24 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 24"
C567CW25 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 25"
C567CW26 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 26"

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| C567CW27 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 27" |
| C567CW28 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 28" |
| C567CW29 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 29" |
| C567CW30 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 30" |
| C567CW31 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 31" |
| C567CW32 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 32" |
| C567CW33 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 33" |
| C567CW34 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 34" |
| C567CW35 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 35" |
| C567CW36 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 36" |
| C567CW37 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 37" |
| C567CW38 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 38" |
| C567CW39 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 39" |
| C567CW40 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 40" |
| C567CW41 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 41" |
| C567CW42 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 42" |
| C567CW43 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 43" |
| C567CW44 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 44" |
| C567CW45 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 45" |
| C567CW46 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 46" |
| C567CW47 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 47" |
| C567CW48 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 48" |
| C567CW49 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 49" |
| C567CW50 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 50" |
| C567CW51 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 51" |
| C567CW52 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 52" |
| C567CW53 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 53" |
| C567CW54 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 54" |
| C567CW55 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 55" |
| C567CW56 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 56" |
| C567CW57 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 57" |
| C567CW58 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 58" |
| C567CW59 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 59" |
| C567CW60 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 60" |
| C567CW61 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 61" |
| C567CW62 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 62" |
| C567CW63 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 63" |
| C567CW64 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 64" |
| C567CW65 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 65" |
| C567CW66 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 66" |
| C567CW67 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 67" |
| C567CW68 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 68" |
| C567CW69 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 69" |
| C567CW70 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 70" |
| C567CW71 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 71" |
| C567CW72 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 72" |
| C567CW73 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 73" |
| C567CW74 | "C5C6C7 CHILD PANEL WEIGHT REPLICATE 74" |

C567CW75 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 75"
C567CW76 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 76"
C567CW77 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 77"
C567CW78 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 78"
C567CW79 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 79"
C567CW80 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 80"
C567CW81 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 81"
C567CW82 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 82"
C567CW83 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 83"
C567CW84 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 84"
C567CW85 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 85"
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C567CW88 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 88"
C567CW89 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 89"
C567CW90 "C5C6C7 CHILD PANEL WEIGHT REPLICATE 90"
C567PW1 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 1"
C567PW2 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 2"
C567PW3 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 3"
C567PW4 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 4"
C567PW5 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 5"
C567PW6 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 6"
C567PW7 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 7"
C567PW8 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 8"
C567PW9 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 9"
C567PW10 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 10"
C567PW11 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 11"
C567PW12 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 12"
C567PW13 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 13"
C567PW14 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 14"
C567PW15 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 15"
C567PW16 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 16"
C567PW17 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 17"
C567PW18 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 18"
C567PW19 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 19"
C567PW20 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 20"
C567PW21 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 21"
C567PW22 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 22"
C567PW23 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 23"
C567PW24 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 24"
C567PW25 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 25"
C567PW26 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 26"
C567PW27 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 27"
C567PW28 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 28"
C567PW29 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 29"
C567PW30 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 30"
C567PW31 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 31"
C567PW32 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 32"

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| C567PW33 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 33" |
| C567PW34 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 34" |
| C567PW35 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 35" |
| C567PW36 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 36" |
| C567PW37 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 37" |
| C567PW38 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 38" |
| C567PW39 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 39" |
| C567PW40 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 40" |
| C567PW41 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 41" |
| C567PW42 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 42" |
| C567PW43 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 43" |
| C567PW44 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 44" |
| C567PW45 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 45" |
| C567PW46 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 46" |
| C567PW47 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 47" |
| C567PW48 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 48" |
| C567PW49 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 49" |
| C567PW50 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 50" |
| C567PW51 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 51" |
| C567PW52 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 52" |
| C567PW53 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 53" |
| C567PW54 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 54" |
| C567PW55 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 55" |
| C567PW56 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 56" |
| C567PW57 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 57" |
| C567PW58 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 58" |
| C567PW59 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 59" |
| C567PW60 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 60" |
| C567PW61 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 61" |
| C567PW62 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 62" |
| C567PW63 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 63" |
| C567PW64 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 64" |
| C567PW65 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 65" |
| C567PW66 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 66" |
| C567PW67 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 67" |
| C567PW68 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 68" |
| C567PW69 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 69" |
| C567PW70 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 70" |
| C567PW71 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 71" |
| C567PW72 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 72" |
| C567PW73 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 73" |
| C567PW74 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 74" |
| C567PW75 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 75" |
| C567PW76 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 76" |
| C567PW77 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 77" |
| C567PW78 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 78" |
| C567PW79 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 79" |
| C567PW80 | "C5C6C7 PARENT PANEL WEIGHT REPLICATE 80" |

C567PW81 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 81"
C567PW82 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 82"
C567PW83 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 83"
C567PW84 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 84"
C567PW85 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 85"
C567PW86 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 86"
C567PW87 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 87"
C567PW88 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 88"
C567PW89 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 89"
C567PW90 "C5C6C7 PARENT PANEL WEIGHT REPLICATE 90"
C7CPTS1 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 1"
C7CPTS2 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 2"
C7CPTS3 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 3"
C7CPTS4 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 4"
C7CPTS5 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 5"
C7CPTS6 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 6"
C7CPTS7 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 7"
C7CPTS8 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 8"
C7CPTS9 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 9"
C7CPTS10 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 10"
C7CPTS11 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 11"
C7CPTS12 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 12"
C7CPTS13 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 13"
C7CPTS14 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 14"
C7CPTS15 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 15"
C7CPTS16 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 16"
C7CPTS17 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 17"
C7CPTS18 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 18"
C7CPTS19 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 19"
C7CPTS20 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 20"
C7CPTS21 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 21"
C7CPTS22 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 22"
C7CPTS23 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 23"
C7CPTS24 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 24"
C7CPTS25 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 25"
C7CPTS26 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 26"
C7CPTS27 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 27"
C7CPTS28 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 28"
C7CPTS29 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 29"
C7CPTS30 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 30"
C7CPTS31 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 31"
C7CPTS32 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 32"
C7CPTS33 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 33"
C7CPTS34 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 34"
C7CPTS35 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 35"
C7CPTS36 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 36"
C7CPTS37 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 37"
C7CPTS38 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 38"

C7CPTS39 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 39"
C7CPTS40 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 40"
C7CPTS41 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 41"
C7CPTS42 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 42"
C7CPTS43 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 43"
C7CPTS44 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 44"
C7CPTS45 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 45"
C7CPTS46 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 46"
C7CPTS47 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 47"
C7CPTS48 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 48"
C7CPTS49 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 49"
C7CPTS50 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 50"
C7CPTS51 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 51"
C7CPTS52 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 52"
C7CPTS53 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 53"
C7CPTS54 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 54"
C7CPTS55 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 55"
C7CPTS56 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 56"
C7CPTS57 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 57"
C7CPTS58 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 58"
C7CPTS59 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 59"
C7CPTS60 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 60"
C7CPTS61 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 61"
C7CPTS62 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 62"
C7CPTS63 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 63"
C7CPTS64 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 64"
C7CPTS65 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 65"
C7CPTS66 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 66"
C7CPTS67 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 67"
C7CPTS68 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 68"
C7CPTS69 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 69"
C7CPTS70 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 70"
C7CPTS71 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 71"
C7CPTS72 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 72"
C7CPTS73 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 73"
C7CPTS74 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 74"
C7CPTS75 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 75"
C7CPTS76 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 76"
C7CPTS77 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 77"
C7CPTS78 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 78"
C7CPTS79 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 79"
C7CPTS80 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 80"
C7CPTS81 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 81"
C7CPTS82 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 82"
C7CPTS83 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 83"
C7CPTS84 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 84"
C7CPTS85 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 85"
C7CPTS86 "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 86"

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  C7CPTS87     "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 87"
  C7CPTS88     "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 88"
  C7CPTS89     "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 89"
  C7CPTS90     "C7 CHILD-PARENT-TCHR(S) WEIGHT REPLIC 90"
  .

VALUE LABELS
 / GENDER
  1  "MALE"
  2  "FEMALE"
  -9  "NOT ASCERTAINED"
 / RACE
  1  "WHITE, NON-HISPANIC"
  2  "BLACK OR AFRICAN AMERICAN, NON-HISPANIC"
  3  "HISPANIC, RACE SPECIFIED"
  4  "HISPANIC, RACE NOT SPECIFIED"
  5  "ASIAN"
  6  "NATIVE HAWAIIAN, OTHER PACIFIC ISLANDER"
  7  "AMERICAN INDIAN OR ALASKA NATIVE"
  8  "MORE THAN ONE RACE, NON HISPANIC"
  -9  "NOT ASCERTAINED"
 / R3SAMPLE
  1  "TRUE"
  0  "FALSE"
 / FKCHGSCH
  1  "TRUE"
  0  "FALSE"
  -1  "NOT APPLICABLE"
  -9  "NOT ASCERTAINED"
 / R4R2SCHG
  1  "CHILD DID NOT CHANGE SCHOOL"
  2  "CHILD TRANSFERRED FROM PUBLIC SCHOOL TO PUBLIC SCHOOL"
  3  "CHILD TRANSFERRED FROM PRIVATE SCHOOL TO PRIVATE SCHOOL"
  4  "CHILD TRANSFERRED FROM PUBLIC SCHOOL TO PRIVATE SCHOOL"
  5  "CHILD TRANSFERRED FROM PRIVATE SCHOOL TO PUBLIC SCHOOL"
  6  "CHILD TRANSFERRED, OTHER"
  -1  "NOT APPLICABLE"
  -9  "NOT ASCERTAINED"
 / R5R4SCHG
  1  "CHILD DID NOT CHANGE SCHOOL"
  2  "CHILD TRANSFERRED FROM PUBLIC SCHOOL TO PUBLIC SCHOOL"
  3  "CHILD TRANSFERRED FROM PRIVATE SCHOOL TO PRIVATE SCHOOL"
  4  "CHILD TRANSFERRED FROM PUBLIC SCHOOL TO PRIVATE SCHOOL"
  5  "CHILD TRANSFERRED FROM PRIVATE SCHOOL TO PUBLIC SCHOOL"
  6  "CHILD TRANSFERRED, OTHER"
  -1  "NOT APPLICABLE"
  -9  "NOT ASCERTAINED"
 / R6R5SCHG
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1 "CHILD DID NOT CHANGE SCHOOL"
2 "CHILD TRANSFERRED FROM PUBLIC SCHOOL TO PUBLIC SCHOOL"
3 "CHILD TRANSFERRED FROM PRIVATE SCHOOL TO PRIVATE SCHOOL"
4 "CHILD TRANSFERRED FROM PUBLIC SCHOOL TO PRIVATE SCHOOL"
5 "CHILD TRANSFERRED FROM PRIVATE SCHOOL TO PUBLIC SCHOOL"
6 "CHILD TRANSFERRED, OTHER"
-1 "NOT APPLICABLE"
-9 "NOT ASCERTAINED"
/ R7R6SCHG
1 "STUDENT DID NOT CHANGE SCHOOL"
2 "STUDENT MOVED FROM PUBLIC SCHOOL TO PUBLIC SCHOOL"
3 "STUDENT MOVED FROM PRIVATE SCHOOL TO PRIVATE SCHOOL"
4 "STUDENT MOVED FROM PUBLIC SCHOOL TO PRIVATE SCHOOL"
5 "STUDENT MOVED FROM PRIVATE SCHOOL TO PUBLIC SCHOOL"
6 "STUDENT MOVED, OTHER"
-1 "NOT APPLICABLE"
-9 "NOT ASCERTAINED"
/ C5R2SSCL
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ C6R2SSCL
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ C7R2SSCL
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ T5ARSSCI
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ T6ARSSCI
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ T7ARSSCI
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ P1FIRKDG

1 "YES"
2 "NO"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ P7DISABL
1 "YES"
2 "NO"
-1 "NOT APPLICABLE"
-9 "NOT ASCERTAINED"
/ W8RACETH
1 "WHITE, NON-HISPANIC"
2 "BLACK OR AFRICAN AMERICAN, NON-HISPANIC"
3 "HISPANIC, RACE SPECIFIED"
4 "HISPANIC, RACE NOT SPECIFIED"
5 "ASIAN"
6 "NATIVE HAWAIIAN, OTHER PACIFIC ISLANDER"
7 "AMERICAN INDIAN OR ALASKA NATIVE"
8 "MORE THAN ONE RACE, NON HISPANIC"
-1 "NOT APPLICABLE"
-9 "NOT ASCERTAINED"
/ W8SESQ5
1 "FIRST QUINTILE"
2 "SECOND QUINTILE"
3 "THIRD QUINTILE"
4 "FOURTH QUINTILE"
5 "FIFTH QUINTILE"
/ T5GLVL
1 "KINDERGARTEN"
2 "FIRST GRADE"
3 "SECOND GRADE"
4 "THIRD GRADE"
5 "FOURTH GRADE"
6 "FIFTH GRADE"
7 "UNGRADED CLASSROOM"
-9 "NOT ASCERTAINED"
/ T6GLVL
0 "KINDERGARTEN"
1 "FIRST GRADE"
2 "SECOND GRADE"
3 "THIRD GRADE"
4 "FOURTH GRADE"
5 "FIFTH GRADE"
6 "SIXTH GRADE"
7 "SEVENTH GRADE"
8 "EIGHTH GRADE"
9 "UNGRADED CLASSROOM"
-9 "NOT ASCERTAINED"
/ T7GLVL

0 "KINDERGARTEN"
1 "FIRST GRADE"
2 "SECOND GRADE"
3 "THIRD GRADE"
4 "FOURTH GRADE"
5 "FIFTH GRADE"
6 "SIXTH GRADE"
7 "SEVENTH GRADE"
8 "EIGHTH GRADE"
9 "NINTH GRADE"
10 "TENTH GRADE"
13 "UNGRADED CLASSROOM"
-9 "NOT ASCERTAINED"
/ C1ASMTMM
9 "SEPTEMBER"
10 "OCTOBER"
11 "NOVEMBER"
12 "DECEMBER"
/ C1ASMTYY
1998 "1998"
/ A5OFTSCI
1 "NEVER"
2 "LESS THAN ONCE A WEEK"
3 "ONCE OR TWICE A WEEK"
4 "THREE OR FOUR TIMES A WEEK"
5 "DAILY"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ A5TXSCI
1 "1-30 MINUTES A DAY"
2 "31-60 MINUTES A DAY"
3 "61-90 MINUTES A DAY"
4 "MORE THAN 90 MINUTES A DAY"
-1 "NOT APPLICABLE"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ J61OFTSC
1 "NEVER"
2 "LESS THAN ONCE A WEEK"
3 "ONCE OR TWICE A WEEK"
4 "THREE OR FOUR TIMES A WEEK"
5 "DAILY"
-7 "REFUSED"
-8 "DON'T KNOW"
-9 "NOT ASCERTAINED"
/ J61TXSCI

```
    1  "1-30 MINUTES A DAY"
    2  "31-60 MINUTES A DAY"
    3  "61-90 MINUTES A DAY"
    4  "MORE THAN 90 MINUTES A DAY"
    -1  "NOT APPLICABLE"
    -7  "REFUSED"
    -8  "DON'T KNOW"
    -9  "NOT ASCERTAINED"
  / N7LIFESC
    -1  "NOT APPLICABLE"
    -7  "REFUSED"
    -8  "DON'T KNOW"
    -9  "NOT ASCERTAINED"
  / N7EARSC
    -1  "NOT APPLICABLE"
    -7  "REFUSED"
    -8  "DON'T KNOW"
    -9  "NOT ASCERTAINED"
  / N7ENVRSC
    -1  "NOT APPLICABLE"
    -7  "REFUSED"
    -8  "DON'T KNOW"
    -9  "NOT ASCERTAINED"
  / N7OTHSC
    -1  "NOT APPLICABLE"
    -7  "REFUSED"
    -8  "DON'T KNOW"
    -9  "NOT ASCERTAINED"
  .

SELECT
  IF (R3SAMPLE EQ 1 OR
     R3SAMPLE EQ 0) AND
    (R4R2SCHG EQ 1 OR
     R4R2SCHG EQ 2) AND
    (R5R4SCHG EQ 1 OR
     R5R4SCHG EQ 2) AND
    (R6R5SCHG EQ 1 OR
     R6R5SCHG EQ 2) AND
    (R7R6SCHG EQ 1 OR
     R7R6SCHG EQ 2) AND
    (P1FIRKDG EQ 1) AND
    (T7GLVL EQ 8).
SAVE OUTFILE =  'G:\Dissertation\Data and Analysis\CorrectedWeight_Dissertation.sav'.

DISPLAY DICTIONARY.

* Frequencies /Variables =
```

```
    GENDER
    RACE
    R3SAMPLE
    FKCHGSCH
    R4R2SCHG
    R5R4SCHG
    R6R5SCHG
    R7R6SCHG
    P1FIRKDG
    P7DISABL
    W8RACETH
    W8SESQ5
    T5GLVL
    T6GLVL
    T7GLVL
    C1ASMTMM
    C1ASMTYY
    A5OFTSCI
    A5TXSCI
    J61OFTSC
    J61TXSCI
/MISSING=INCLUDE.

* Descriptive VARIABLES=
    C567CW0
    C7CPTS0
    C5R2SSCL
    C6R2SSCL
    C7R2SSCL
    T5ARSSCI
    T6ARSSCI
    T7ARSSCI
    C1ASMTDD
    N7LIFESC
    N7EARSC
    N7ENVRSC
    N7OTHSC
    C567CW1
    C567CW2
    C567CW3
    C567CW4
    C567CW5
    C567CW6
    C567CW7
    C567CW8
    C567CW9
    C567CW10
    C567CW11
```

C567CW12
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C567PW89
C567PW90
C7CPTS1
C7CPTS2
C7CPTS3
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    C7CPTS86
    C7CPTS87
    C7CPTS88
    C7CPTS89
    C7CPTS90
.

*Recoding Variables from -9, -8, or -1 to System Missing.

DATASET ACTIVATE DataSet1.
RECODE GENDER RACE C5R2SSCL C6R2SSCL C7R2SSCL FKCHGSCH R4R2SCHG R5R4SCHG
R6R5SCHG R7R6SCHG T5ARSSCI
   T5LEARN T6ARSSCI T6LEARN T7ARSSCI P1FIRKDG P7DISABL W8RACETH T5GLVL T6GLVL
T7GLVL S2KPUPRI S4PUPRI
   S5PUPRI S6PUPRI S7PUPRI C6ASMTMM C6ASMTDD C6ASMTYY C7ASMTMM C7ASMTDD
C7ASMTYY A5OFTSCI A5TXSCI
   J61OFTSC J61TXSCI N7LIFESC N7EARSC N7ENVRSC N7OTHSC (Lowest thru -1=SYSMIS).
EXECUTE.

*Recoding demographic variables.

*Male = 0, Female = 1.

RECODE GENDER (1=0) (2=1).
EXECUTE.

*No Disability = 0, Disability = 1.

RECODE P7DISABL (2=0) (1=1).
EXECUTE.

*First Time K = 0, Non-First Time K = 1.

RECODE P1FIRKDG (1=0) (2=1).
```

```
EXECUTE.

*Low SES =1, Middle SES (2, 3, 4) = 2, High SES = 3.

RECODE W8SESQ5 (1=1) (5=3) (2 thru 4=2).
EXECUTE.

*Verification of ONLY analyzing first-time kindergarteners.

FREQUENCIES VARIABLES=P1FIRKDG
  /ORDER=ANALYSIS.

USE ALL.
COMPUTE filter_$=(P1FIRKDG = 0).
VARIABLE LABEL filter_$ 'P1FIRKDG = 0 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMAT filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

*Applying weights to the data set.

WEIGHT BY C567CW0.

*Obtaining descriptives separated  by subgroups.

SORT CASES  BY GENDER.
SPLIT FILE SEPARATE BY GENDER.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SORT CASES  BY P7DISABL.
SPLIT FILE SEPARATE BY P7DISABL.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SORT CASES  BY W8RACETH.
SPLIT FILE SEPARATE BY W8RACETH.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SORT CASES  BY W8SESQ5.
SPLIT FILE SEPARATE BY W8SESQ5.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

*Obtaining descriptives separated by subgroups without the application of weights.
```

```
WEIGHT OFF.

SORT CASES  BY GENDER.
SPLIT FILE SEPARATE BY GENDER.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SORT CASES  BY P7DISABL.
SPLIT FILE SEPARATE BY P7DISABL.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SORT CASES  BY W8RACETH.
SPLIT FILE SEPARATE BY W8RACETH.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SORT CASES  BY W8SESQ5.
SPLIT FILE SEPARATE BY W8SESQ5.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE OFF.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

WEIGHT BY C567CW0.
DESCRIPTIVES VARIABLES=C5R2SSCL C6R2SSCL C7R2SSCL
  /STATISTICS=MEAN STDDEV MIN MAX.

FREQUENCIES VARIABLES=W8RACETH
  /ORDER=ANALYSIS.

WEIGHT OFF.

FREQUENCIES VARIABLES=W8RACETH
  /ORDER=ANALYSIS.

WEIGHT BY C567CW0.
FREQUENCIES VARIABLES=GENDER
  /ORDER=ANALYSIS.

WEIGHT OFF.
FREQUENCIES VARIABLES=GENDER
  /ORDER=ANALYSIS.

*Obtaining unweighted and weighted descriptives for frequency, duration, and time devoted to
science variables.
```

```
DESCRIPTIVES VARIABLES=A5OFTSCI A5TXSCI
  /STATISTICS=MEAN STDDEV VARIANCE MIN MAX.

WEIGHT BY C567CW0.
DESCRIPTIVES VARIABLES=A5OFTSCI A5TXSCI
  /STATISTICS=MEAN STDDEV VARIANCE MIN MAX.

WEIGHT OFF.
FREQUENCIES VARIABLES=A5OFTSCI A5TXSCI
  /STATISTICS=STDDEV VARIANCE RANGE MINIMUM MAXIMUM MEAN
  /BARCHART FREQ
  /ORDER=ANALYSIS.

WEIGHT BY C567CW0.
FREQUENCIES VARIABLES=A5OFTSCI A5TXSCI
  /STATISTICS=STDDEV VARIANCE RANGE MINIMUM MAXIMUM MEAN
  /BARCHART FREQ
  /ORDER=ANALYSIS.

*Science Academic Rating Scales, Descriptives.

*Recoding Variables from -9, -8, or -1 to System Missing.

DATASET ACTIVATE DataSet1.
RECODE GENDER RACE C5R2SSCL C6R2SSCL C7R2SSCL FKCHGSCH R4R2SCHG R5R4SCHG
R6R5SCHG R7R6SCHG T5ARSSCI
    T6ARSSCI T7ARSSCI P1FIRKDG P7DISABL W8RACETH T5GLVL T6GLVL T7GLVL A5OFTSCI
A5TXSCI
    J61OFTSC J61TXSCI N7LIFESC N7EARSC N7ENVRSC N7OTHSC (Lowest thru -1=SYSMIS).
EXECUTE.

*Recoding demographic variables.

*Male = 0, Female = 1.

RECODE GENDER (1=0) (2=1).
EXECUTE.

*No Disability = 0, Disability = 1.

RECODE P7DISABL (2=0) (1=1).
EXECUTE.

*Low SES =1, Middle SES (2, 3, 4) = 2, High SES = 3.

RECODE W8SESQ5 (1=1) (5=3) (2 thru 4=2).
EXECUTE.
```

```
*Demographics of subsample of children with Science Academic Rating Scale Scores.

FREQUENCIES VARIABLES=GENDER W8RACETH
  /ORDER=ANALYSIS.

WEIGHT BY C7CPTS0.

FREQUENCIES VARIABLES=GENDER W8RACETH
  /ORDER=ANALYSIS.

*8th Grade Science Academic Rating Scales, Descriptives.

DESCRIPTIVES VARIABLES=T7ARSSCI
  /STATISTICS=MEAN STDDEV MIN MAX.

FREQUENCIES VARIABLES=T7ARSSCI
  /NTILES=3
  /ORDER=ANALYSIS.

*Recoding Science Academic Rating Scale into High, Medium, and Low.

RECODE T7ARSSCI (Lowest thru 2.67=1) (2.68 thru 3.64=2) (3.65 thru Highest=3) INTO
T7ARSSCI_3GROUPS.
VARIABLE LABELS  T7ARSSCI_3GROUPS 'T7ARSSCI_3GROUPS'.
EXECUTE.

*Science Academic Rating Scale Across Demographic Groups, Unweighted.

DATASET ACTIVATE DataSet1.
SORT CASES  BY GENDER.
SPLIT FILE SEPARATE BY GENDER.

DESCRIPTIVES VARIABLES=T7ARSSCI
  /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.

DATASET ACTIVATE DataSet1.
SORT CASES  BY W8SESQ5.
SPLIT FILE SEPARATE BY W8SESQ5.

DESCRIPTIVES VARIABLES=T7ARSSCI
  /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.

DATASET ACTIVAT DataSet1.
```

```
SORT CASES BY P7DISABL.
SPLIT FILE SEPARATE BY P7DISABL.

DESCRIPTIVES VARIABLES=T7ARSSCI
 /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.

DATASET ACTIVAT DataSet1.
SORT CASES BY W8RACETH.
SPLIT FILE SEPARATE BY W8RACETH.

DESCRIPTIVES VARIABLES=T7ARSSCI
 /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.

*Science Academic Rating Scale Across Demographic Groups, Weighted.

DATASET ACTIVATE DataSet1.
WEIGHT BY C7CPTS0.

DATASET ACTIVATE DataSet1.
SORT CASES  BY GENDER.
SPLIT FILE SEPARATE BY GENDER.

DESCRIPTIVES VARIABLES=T7ARSSCI
  /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.

DATASET ACTIVATE DataSet1.
SORT CASES  BY W8SESQ5.
SPLIT FILE SEPARATE BY W8SESQ5.

DESCRIPTIVES VARIABLES=T7ARSSCI
  /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.

DATASET ACTIVAT DataSet1.
SORT CASES BY P7DISABL.
SPLIT FILE SEPARATE BY P7DISABL.

DESCRIPTIVES VARIABLES=T7ARSSCI
 /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.
```

```
DATASET ACTIVAT DataSet1.
SORT CASES BY W8RACETH.
SPLIT FILE SEPARATE BY W8RACETH.

DESCRIPTIVES VARIABLES=T7ARSSCI
 /STATISTICS=MEAN STDDEV MIN MAX.

SPLIT FILE Off.


*Modification of variables for the modified conditional model.


DATASET ACTIVATE DataSet1.
RECODE W8RACETH (1=1) (2=2) (3=3) (4=3) (5=5) (6=6) (7=6) (8=8).
EXECUTE.

RECODE W8RACETH (2=1) (SYSMIS=SYSMIS) (ELSE=0) INTO NewRACETHDummy1.
VARIABLE LABELS  NewRACETHDummy1 'NewRACETHDummy1'.
EXECUTE.

RECODE W8RACETH (3=1) (SYSMIS=SYSMIS) (ELSE=0) INTO NewRACETHDummy2.
VARIABLE LABELS  NewRACETHDummy2 'NewRACETHDummy2'.
EXECUTE.

RECODE W8RACETH (5=1) (SYSMIS=SYSMIS) (ELSE=0) INTO NewRACETHDummy3.
VARIABLE LABELS  NewRACETHDummy3 'NewRACETHDummy3'.
EXECUTE.

RECODE W8RACETH (6=1) (SYSMIS=SYSMIS) (ELSE=0) INTO NewRACETHDummy4.
VARIABLE LABELS  NewRACETHDummy4 'NewRACETHDummy4'.
EXECUTE.

RECODE W8RACETH (8=1) (SYSMIS=SYSMIS) (ELSE=0) INTO NewRACETHDummy5.
VARIABLE LABELS  NewRACETHDummy5 'NewRACETHDummy5'.
EXECUTE.

RECODE W8SESQ5 (Lowest thru 2.11=0) (2.12 thru Highest=1) INTO NewSES.
VARIABLE LABELS  NewSES 'NewSES'.
EXECUTE.
```