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A Study of the Relationships Between Student Achievement on the TIMSS-2007 and Constructivist Teaching Pedagogy and Class Size

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Abstract

Eighth grade students from the United States have historically achieved at mediocre levels on the Trends in International Mathematics and Science Study (TIMSS). It would be useful for educators to know which characteristics within the classroom allow for the largest improvement in the TIMSS score. In this study hierarchical linear modeling (HLM) was used to investigate the association between; (a) frequency of constructivist teaching strategies used in the classroom and eighth grade student achievement, (b) number of students in a class and eighth grade student achievement, (c) class size and frequency of constructivist teaching strategies used in the classroom. The findings of this study have shown that constructivist teaching strategies did not have an association with student achievement on the science portion of the TIMSS2007. The findings also suggested that a relationship did not exist between classroom size and the frequency a teacher used constructivist teaching in the classroom. The analysis has also shown that a relationship did not exist between class size and student achievement. The major implications of these findings suggested that; (a) educational policymakers should allow teachers to have free reign in deciding what teaching strategy will work best in the classroom (b) school districts cannot rely on decreasing class size to motivate teachers to increase their frequency of constructivist teaching, and (c) school districts can save money by increasing the number of students in an eighth grade science class without worry of decreasing the student's achievement.

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Dedication

I would like to thank the many people who have been instrumental in providing me guidance and support while completing this study.

The direction and knowledge provided to me by my dissertation chairman Dr. Guillermo Montes and my dissertation committee member Dr. Bruce Blaine was exceptional. I also would like to express gratitude to Jan Lutterbein and Jim Hurny for their encouragement and mentoring.

Most importantly I would like to thank my family for their steadfast love and support during this process. My loving wife Marcia has been an uplifting and reassuring supporter who always encourages me to reach my goals: my wonderful children Allison, Kevin and Brian have been an inspiration for me to always want to do my best work: my parents Rudy and Nancy have always been my role models and teachers in many things, especially knowing the importance of an education that never ends.

Biographical Sketch

Robert Enck is currently the Lead Science Teacher and a Physics Teacher at Webster Schroeder High School. Enck attended SUNY Brockport College from 1983 to 1987 and graduated with a Bachelor of Sciences degree in 1987. He attended SUNY Brockport College from 1991 to 1993 and graduated with a Master of Sciences Degree in 1993. He came to St. John Fisher College in the summer of 2009 and began doctoral studies in the Ed.D. Program in Executive Leadership. Mr. Enck pursued his research in how teaching strategies are associated with student achievement in science under the direction of Dr. Guillermo Montes and received the Ed.D. degree in 2011.

Abstract

Eighth grade students from the United States have historically achieved at mediocre levels on the Trends in International Mathematics and Science Study (TIMSS). It would be useful for educators to know which characteristics within the classroom allow for the largest improvement in the TIMSS score. In this study hierarchical linear modeling (HLM) was used to investigate the association between; (a) frequency of constructivist teaching strategies used in the classroom and eighth grade student achievement, (b) number of students in a class and eighth grade student achievement, (c) class size and frequency of constructivist teaching strategies used in the classroom.

The findings of this study have shown that constructivist teaching strategies did not have an association with student achievement on the science portion of the TIMSS-2007. The findings also suggested that a relationship did not exist between classroom size and the frequency a teacher used constructivist teaching in the classroom. The analysis has also shown that a relationship did not exist between class size and student achievement.

The major implications of these findings suggested that; (a) educational policy-makers should allow teachers to have free reign in deciding what teaching strategy will work best in the classroom (b) school districts cannot rely on decreasing class size to motivate teachers to increase their frequency of constructivist teaching, and (c) school districts can save money by increasing the number of students in an eighth grade science class without worry of decreasing the student's achievement.

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Chapter 1: Introduction

Background of the Study

For many years the United States has been warned about the need to improve the K-12 educational system. In 1983 the National Commission on Excellence in Education presented a report titled *A Nation at Risk*. The report stated “If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves.” (National Commission on Excellence in Education, 1983, p9). The Commission called for major changes in the United States education system due to the low scores on international tests compared to other countries such as Singapore, Japan and Chinese Taipei. The commission noted that the threat to our country was from losing sight of the basic purposes of education. The report provided recommendations to the United States Department of Education and Congress for sweeping changes throughout the United States educational system (National Commission on Excellence in Education, 1983).

In 2008 the National Commission on Excellence in Education released another report on the condition of the United States K-12 education system titled *A Nation Accountable: Twenty Five Years after a Nation at Risk.* This report declared that we are now a nation at even more risk than we were in 1983. The 2008 report affirmed that out of twenty students who were born in 1983, fourteen of those students would graduate on time in 2001. Of those fourteen students, ten would attend college in the fall of 2001.

Only five of the ten students would then graduate from college by the year 2007. The 2008 report analyzed why the college graduation rates were low. It showed that many meaningful suggestions in the original 1983 report had not been implemented. The Commission also suggested that many of the changes that have occurred gave the illusion that progress was being made when it actually was not. The level of teaching quality and the training of teachers in best teaching practices and effective teaching pedagogy was an additional area that the report showed as needing improvement. The Commission noted that while recent laws passed by Congress have mandated the resource inputs of teacher improvement programs they have not demanded the proof of learning outcomes for teacher improvement. This approach to improving teacher quality leads to spending money without requiring effective results (National Commission on Excellence in Education, 2008).

Lack of achievement in secondary science education in the United States. The educational system in the United States has produced students that scored slightly above average on the four most recent eighth grade international science achievement studies with no significant increase during those years (Gonzales, Williams, Jocelyn, Roey, Kastberg & Brenwald, 2009).

Countries such as Singapore, Chinese Taipei and Japan are considered to have the highest achieving students in science. The reasons for this dramatic difference of student achievement are a concern for not only the United States educational system, but also for the economy and national security of the United States (National Commission on Excellence in Education, 1983).

The relationship between classroom size and student achievement. Classroom size may have had a relationship with student achievement in the science portion of the eighth grade TIMSS-2007. Many of the highest scoring countries had the largest classroom sizes. Singapore had an average classroom size of 38 students, Chinese Taipei had an average classroom size of 35 students and Japan had an average classroom size of 35 students. The United States had an average classroom size of 28 students (Martin, Mullis, & Foy, 2008).

Analyzing how classroom size affects student achievement in the United States and how classroom size affects the pedagogy of the teacher can give educators information about how to organize their classrooms, and can also help school districts understand how to be most effective and efficient. Maximizing classroom size with the greatest efficiency may have economic implications for the school district as well as influence teacher pedagogy.

The Trends in International Mathematics and Science Study (TIMSS). One way of determining how well United States students are learning compared to their peers from other countries is to use standardized international tests such as the Trends in International Mathematics and Science Study (TIMSS). These data provided information concerning the national educational system, the practices of the school and teachers that the student interacts with, and the characteristics of the student's environment outside of the school setting. The purpose of the TIMSS is to provide data to be analyzed by policymakers and educators in order to make informed decisions based on relationships found between student success and policy practices (Martin et al., 2008).

The TIMSS is a study that collects data on fourth and eighth grade students and their schools. The TIMSS has been administered every four years, starting in 1995 and continuing in the years 1999, 2003 and 2007. The most recent study conducted by the IEA was the TIMSS-2007, which involves approximately 425,000 students from 59 countries around the world [National Center for Education Statistics (ED), 2007]. The studies have purposefully been longitudinal in nature to allow each country that participates in the study the ability to follow trends in data. These four TIMSS reports, gives the countries a 12- year view of student achievement at four different points of time leading up to and including 2007. This information may lead countries to correctly identify areas of concern and then implement possible solutions for educational reform (Gonzales et al., 2009) .

The TIMSS was conducted by the International Association for the Evaluation of Educational Achievement (IEA). The IEA was founded by a group of scholars in 1958 as an international cooperative of national research institutions and government agencies. Since this date they have conducted more than 23 international educational research studies that work towards providing data and information that educational policymakers can use to make informed decisions about their country's educational system (Brief History of IEA, 2007).

The development of the TIMSS was done with a wide variety of people helping to arrive at a final product. An international panel of mathematics and science education and testing experts decide on a conceptual framework to be used for testing students. The IEA developed the assessment in a collaborative fashion and included experts in the field of mathematics and science as well as education, from around the world. Experts from each of the participating countries were allowed to give input as the frameworks were developed. The participating countries also completed questionnaires about curriculum content. These questionnaires allowed the TIMSS conceptual framework to include the substantial topics that the countries felt were important to assess at the fourth and eighth grade level (Mullis et al., 2005).

The TIMSS tested a sample of students from each participating country at the fourth and eighth grade level on their knowledge of mathematics and science. The effective target population for the TIMSS was specifically defined by the IEA as being the grades that represented four or eight years of schooling starting at the primary grade. The average age of the students could not be less than 9.5 years for fourth grade and 13.5 years for eighth grade. This definition was called the international desired target population. Each country then defined a national desired target population that closely matched the international desired target population. These definitions of desired target populations had to be consistent throughout the years for each country since the TIMSS is a longitudinal comparative study (Olson, Martin, & Mullis, 2008).

The TIMSS used a two-stage cluster design to randomly choose classrooms. During the first stage, schools were sampled with a probability of being chosen proportional to student population and during the second stage one or more classrooms were randomly chosen within the chosen schools. The hierarchical characteristic of the sample population, with students nested inside of classrooms which were nested within schools, allowed for the sampling method of two-stage probability-proportional to size sampling technique. Stratification at the school level was used to improve the efficiency of the sample design as well as select sample groups within the population at the proper proportion and make sure all groups were represented correctly. The stratification of schools was used to make sure the student sample chosen at random closely matched the characteristics of the general population (Olson et al., 2008).

To assist with analysis of achievement scores the IEA broke up the achievement levels of all countries into categories called benchmarks. These benchmarks showed the range of student performance and the number of students distributed into each benchmark for every country. The four different benchmarks for the TIMSS-2007 were Advanced International Benchmark, with a score of 625 or higher; the High International Benchmark, with a score of 550-624; the Intermediate International Benchmark, with a score of 475-549; and the Low International Benchmark, with a score of 400-474 (Martin et al., 2008).

Theoretical Rationale: Constructivist Learning Theory

Cognitive psychologists believe that learning is a constructive process. Students learn by using what they know to help with learning new material they encounter. The teacher in the classroom has a role of coaching students as they further construct their knowledge. The teacher will enable students to build upon previous knowledge by constructing mental scaffolding within the classroom that the student can use to gain and build new knowledge. Scaffolding consists of a wide variety of tools that the teacher can use to assist the students' learning. It can range from a formally planned activity to simply giving hints and encouragement that will help students move back in the right direction when they become stuck in one place and do not know how to move forward to solve a problem. It is important for teachers who use a constructivist approach for teaching, to consider the social aspects of learning. Teachers may allow students to interact with their classmates in small group discussions in order to elaborate and clarify what they are learning. The process of peer review allows for the students to internalize methods of expression and reflection which lead to higher levels of cognitive activity (Bruning, Schraw, Norby, & Ronning, 2004). The teacher plays an important role in educating the student with a constructivist approach. The teacher's qualifications as well as the teaching pedagogy may determine how well students learn and perform in the classroom.

The constructivist learning theory is the basis for a teaching strategy that some educators believe allows students to learn not only the material being studied but also to learn how to analyze situations, synthesize and evaluate problems, and successfully approach issues. Constructivist learning theory states that students learn by building new knowledge on top of knowledge that was previously learned. This teaching approach allows the student to build a scaffolding of understanding and comprehension from their classroom experiences which will allow the student to continue their learning (von Glasersfeld, 2001).

The constructivist learning theory has four essential characteristics. First, the student uses prior knowledge to build upon in order for new learning to occur. This process leads to cognitive dissonance, the second characteristic of constructivist learning theory. The student realizes that their past knowledge cannot answer the new questions and thus, new learning must occur in order to improve and build upon the previous knowledge. The third characteristic of the constructivist learning process is testing of new knowledge for validity by application and feedback. For the new knowledge to become part of the student's structure of knowledge there must be an application of the new ideas so that old knowledge and new knowledge can reach interconnectedness that allows the student to obtain a mental equilibrium and resolve the cognitive dissonance. The last characteristic of the constructivist learning process occurs when the student reflects upon the new knowledge and shows how the information is now internalized. This gives the student and teacher an opportunity to realize whether the desired learning has occurred. Reflection can range from a formal written paper assignment to an informal discussion with a partner. Constructivist learning theory focuses on how a student learns, not on how a teacher should teach. Since this approach focuses on learning, it is compatible with many different teaching styles (Baviskar, Hartle, & Whitney, 2009).

Problem Statement

Educators are constantly searching for the most effective way to teach students and have many choices of how to present information and concepts to a class. One possible teaching strategy to choose from is a constructivist approach of inquiry learning. Constructivist learning theory states that students who have opportunities to construct their own knowledge, learn not only the material being studied but also conceptual problem solving skills. This learning approach allows the student to build a scaffolding of understanding and comprehension from their classroom experiences (von Glasersfeld, 2001).

Another aspect of improving a student's education is to investigate how class size affects student achievement and the implications it may have on teaching pedagogy. The reason this may be of interest is that class size is a characteristic within a school that can be controlled. School districts can change class sizes to match the highest student achievement possible with the lowest cost of educating the students. School districts typically want to have their students achieve at the highest level for the least amount of money. Understanding the relationship between class size and student achievement allows for school districts to have an effective educational system.

The other aspect of class size that should be investigated is how the number of students in the room affects the learning approach in the class. Educators may want to know if a school maximizes the class size, will the frequency of constructivist teaching strategies used in the classroom change. Knowing the effect of class size on student achievement and the teacher's ability to have students learn in a constructivist approach can be investigated with the TIMSS data.

Research Questions

The research questions for this study investigated the relationships of student achievement for the United States on the TIMSS-2007 compared to possible influencing factors. The research questions were the following:

1. What is the relationship between the use of constructivist teaching strategies and student achievement scores on the TIMSS-2007 for eighth grade science students in the United States?

2. How is class size related to both eighth grade science teachers' pedagogical approaches and eighth grade science students' achievement scores on the TIMSS 2007?

3. What are the relationships discussed above for both suburban and urban schools?

A graphical representation of these three research questions is shown in Figure 1.1.

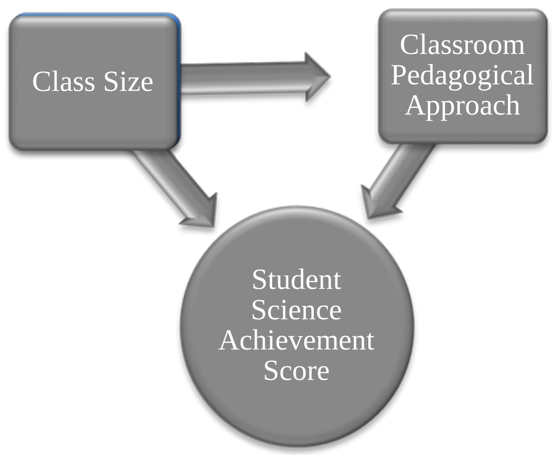

Figure 1.1 Graphical representation of research questions.

Significance of the Study

In 2005 the National Academies presented a report to members of Congress which emphasized the critical junction that the United States is coming to with regards to the nation's ability to prosper and lead the global economy into the 21st century. This group was asked by Congress to research the reasons why the United States is experiencing a decrease in the ability to compete globally and how the U.S. can sustain its current leadership in technology and science. The National Academies' report to Congress emphasizes that changes to the K-12 education system must be made with great urgency in order to help the U.S. hold onto its strategic and economic security (Augustine, Whitesides, & Bissell, 2007).

In 2006, the Association of American Universities (AAU) reported that the decline in U.S. students' mathematics and science abilities is a major threat to this country's global economic leadership. This report identified the grave issues in our educational system likely to cause the U.S. to lose its competitive economic position.

Furthermore, the AAU viewed the economic deterioration as a national security threat. With this in mind, the AAU called for the President, Congress, academia, and business to collaborate and put into place a 21st Century National Defense Education and Innovation Initiative, which will meet the economic and security challenges the U.S. will face for the next 50 years.

The AAU presented recommendations that universities and the government can take to meet these challenges. They also presented data that show a clear decline in performance of U.S. students in mathematics and science. The AAU stated that this is a critical issue. These low scores lead to U.S. students avoiding mathematics and science careers. Within a few short years it was estimated that China will be producing more Ph.D. students in the sciences than the U.S. The end result must be an increase in our students' abilities to learn mathematics and science and follow career paths in these areas to help make sure the U.S. maintains its competitive edge. The AAU points to *Rising Above the Gathering Storm* as a landmark report by the National Academies to guide educators and policymakers in following recommended changes for improving student achievement (Hasselmo, 2006).

The National Academies was charged by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources, as well as an endorsement by Representative Sherwood Boehlert and Representative Bart Gordon of the House Committee on Science to decide on the top ten actions the policymakers should take to improve and enhance the science and technology enterprise so that the United States can be competitive in the global economy. The National Academies responded by forming the Committee on Prospering in the Global Economy of the 21st

Century. The committee studied the issue with a wide focus of possibilities of improving the competiveness of the United States and decided that the highest priority for policymakers should be to recruit the brightest students to become teachers. The report also states that these new teachers as well as current teachers should be trained in the most effective teaching strategies, such as inquiry based learning. The report states that summer institutes should provide training in inquiry based learning to allow teachers to provide students with valuable laboratory experiences (Augustine et al., 2007). The *Rising Above the Gathering Storm* report shows the significance in implementing the most effective teaching strategies for not only improving education but also as a strategy for keeping the United States competitive in a global economy.

Chapter Summary

The problem of United States students not being as highly educated in science as students from industrialized countries across the world is significant. The high competitiveness of a global economy allows for the best educated students to be chosen for the most influential and higher paying jobs, regardless of where they were born. The future of the United States' ability to be a leader in the global economy relies heavily on the ability to educate students at a high level. Right now this is not happening and the educators of the United States may want to consider research data from the TIMSS-2007 to help with this educational dilemma.

Chapter 2: Review of the Literature

Introduction and Purpose

The review of the literature focuses on quantitative studies that exclusively analyze TIMSS data. The research investigating TIMSS data may provide relationships between variables associated with the student, teacher, and school TIMSS surveys as well as the TIMSS scores of the students. Researchers and educators were continuously attempting to find what educational environment will allow students to achieve at their highest potential. The core objective of the IEA in providing the TIMSS to countries across the world is to help educators learn what pedagogical approaches will be most effective in the classroom (Martin et al., 2008). Researchers also investigate and look for relationships that show why students from certain countries score much higher on the TIMSS than others.

Educational researchers and policymakers have been investigating the large achievement gap that exists between students of the United States and students of other countries such as Singapore and Japan. One possible area to explore to understand this achievement gap is the pedagogical approach of teachers in the United States. When the most effective teaching strategies have been identified, a change in the United States educational system may be successful. Identifying the classroom characteristics that support these learning strategies may be useful as well.

Review of Empirical Studies

The TIMSS have a large number of covariates for researchers to analyze and report findings that inform policymakers on the characteristics of the educational system. A review of the literature that analyzes the eighth grade science section of the past TIMSS may further assist researchers to understand these characteristics.

Relationships between covariates and student achievement comparisons of United States scores with scores from other countries. The International Association for the Evaluation of Educational Achievement (IEA) recently released the TIMSS-2007 International Science Report. The purpose of this report was to allow policymakers from the 59 participating countries to make informed decisions about science education reform. To allow for a clear understanding of the data, Item Response Theory (IRT) scaling was used to construct a reliable measure for student achievement. This scaling allowed for the mean average of all participating countries to be 500 with a standard deviation of 100. To improve accuracy of these results a conditioning technique was also used. Each student only answered a small percentage of the possible questions being distributed. The student's background and characteristics were taken into account to allow for an estimate of how the student would perform on the rest of the questions that they were not given (Olson et al., 2008).

The TIMSS-2007 International Science Report of eighth grade students showed that the United States was ranked 11th with an average scale score of 520. The top four scoring countries were from Asia and have the following average scale scores: Singapore (567), Chinese Taipei (561), Japan (554), and Korea (553). The following countries also performed better than the United States: England (542), Hungary (539), Czech Republic

(539), Slovenia (538), Hong Kong (530), and the Russian Federation (530). It was found that the difference between the 95th percentile and the 5th percentile within many countries was approximately 300 scale points, which was similar to the difference between the median scale score of the highest achieving country, Singapore (567) and the lowest achieving country Ghana (303). In the eighth grade TIMSS-2007 International Science Report, eleven countries had higher average scores, eight countries showed lower average scores, and sixteen showed no significant change in scores compared to their initial TIMSS average scaled scores in 1995. The United States has had no significant change in the eighth grade science scores since 1995. The 1995 score for the United States was 513 and the 2007 score was 520 (Martin et al., 2008).

Conceptual teaching in the United States compared to other countries. Educational reform in the United States may consist of an increased number of teachers using a constructivist approach to teaching. A constructivist approach would allow for a balance of conceptual teaching and computational teaching methods. Researchers analyzed TIMSS-1999 data to find how often United States teachers use conceptual teaching compared to computational teaching and what barriers United States teachers perceive to increasing conceptual teaching strategies. The study also compared how the perceived barriers to instructional strategies in other countries differ from the United States and what effect it has in the classroom. Conceptual teaching occurs when students spend time solving real life examples and problems. They reflect upon their answers and give support to why the answer they have was correct. The student may also present alternative ideas by investigating the problem further. The student was involved in deciding on the problem solving steps and working with others to decide if the process was correct. This approach to learning allows for the students to improve their problem solving skills. Procedural or computational teaching typically does not allow for a deeper understanding by the student. The student was asked to memorize a procedure when solving a problem and was not required to explain why the answer was correct (Desimone, Smith, Baker, & Ueno, 2005).

The authors used the TIMSS data to find the relative frequency between eighth grade mathematics teachers in the United States using conceptual teaching compared to computational teaching. The authors also analyzed what perceived barriers exist for eighth grade mathematics teachers to use the conceptual teaching strategy and whether these barriers truly exist. The sample used for this study was the 6,171 eighth grade mathematics teacher surveys that were fully completed from the 38 countries that participated in the TIMSS-1999 (Desimone et al., 2005).

Definitions of conceptual teaching and computational teaching and how to interpret questions from the TIMSS teacher survey to score the teaching strategies used by the teacher were agreed upon by the researchers. The question, “How often do you ask students to practice computational skills?” was used to assess the amount of computational teaching in the classroom. The following four questions were used to score the teacher’s level of conceptual teaching: (a) how often do you ask students to explain reasoning behind an idea, (b) how often do you ask students to use tables, charts, or graphs, (c) how often do you ask students to work on problems with no obvious method of solution, and (d) how often do you ask students to write equations to represent relationships? The answers to the above questions used the following scale: (1) never, (2) some lessons, (3) most lessons, and (4) every lesson. Exploratory factor analyses were done with the teacher data from all 38 countries in the TIMSS-1999 data set. The analysis was done while the variables, number of books in the home (proxy for socio-economic status) and the average achievement of the class, were controlled. The teacher's content knowledge was measured by the level of the teacher's degree in the field being taught and number of years of teaching experience (Desimone et al., 2005).

The results of this study showed a tendency for United States teachers to teach high achieving students with a conceptual approach more often than low achieving students. It was also shown that the United States teachers have a tendency to teach low achieving students with computational methods. The high achieving countries, Japan and Singapore, do not show as strong a tendency to teach lower achieving students with the computational approach. Japanese and Singapore teachers were just as likely to use conceptual teaching methods in a low achieving class as they were with a high achieving class. This difference in teaching approaches may be an explanation for why low achieving students in the United States score so low on the TIMSS when compared to low achieving students from these two countries (Desimone et al., 2005).

Investigation of the relationship between classroom activities when students learn a new science topic and student achievement on the TIMSS-1999. The TIMSS-99 video study of eighth grade science teaching was a follow-up study and an expansion upon the TIMSS-95 video study. The purpose of the study was to analyze and compare the learning characteristics of eighth grade science classrooms in five countries that achieved at a very high level on the TIMSS-99 exam. The focus of the video analysis was to observe how teacher actions provided opportunities for students to learn science. The three main questions used to guide the research were: (a) how did the teacher organize the lesson to provide a learning opportunity for the student, (b) how was science represented to the students in the classroom, and (c) what opportunities did students have to learn science through activities? These classroom characteristics were then analyzed to help understand which teacher strategies related to high achievement of students. The sample for this study consisted of five countries: Australia, the Czech Republic, Japan, the Netherlands, and the United States. The four foreign countries were chosen because they all outperformed the United States in both the mathematics and science portion of the TIMSS-1995. The 1999 TIMSS video study included 439 eighth grade science lessons with each country sampling 100 schools. The participation rate varied from 81% of schools approached in Australia and the United States to 100% of schools approached in the Czech Republic. The eighth grade science classes were randomly chosen from each participating school. The randomly chosen class was videotaped for one lesson only. Within each country the classes were videotaped across the span of the school year so that a variety of lessons would be recorded. These video lessons were coded by a wide variety of specialists. Inter-rater reliability was achieved through consensus coding. Comparisons of the data have been made statistically significant at the .05 level (Gonzales, 2006).

The results of the study showed similarities and differences of approach to teaching, along with student achievement across these five countries. Two teaching strategies were found to be common among the four higher achieving countries but not found in the United States. These characteristics include high content standards and high expectations for student learning. The second feature that was found in the four high achieving countries showed teachers using a content-focused instructional approach that was consistent within the classroom. It was found that the teachers in the United States used variety instead of consistency within the lessons. United States teachers present topics with a large variety of mental stimuli to reach all learning styles. It was understood by many teachers in the U.S. that some students learn best with visuals, others are auditory learners, while other students learn best by reading and writing. Teachers try to provide information to all learning styles within one lesson. The United States teachers have a tendency to introduce a variety of topics and use a variety of pedagogical approaches during a single lesson (Gonzales, 2006).

A study to further investigate learning strategies that may help to improve student achievement was completed using TIMSS-1995 data. The researchers looked at six different methods of introducing a mathematics topic and investigated how effective each method was with regards to student achievement. The six teaching strategies for teaching eighth grade mathematics were: (a) having the teacher explain the rules and definitions, (b) discussing a practical or story problem related to everyday life, (c) working together in pairs or small groups on a problem project, (d) having the teacher ask the student what they know related to the new topic, (e) having the student look at the textbook while the teacher talks about it, and (f) trying to solve an example related to the new topic. The researchers used Canadian data from the TIMSS-1995 and looked at six mathematical topic areas including mathematics as a whole, algebra, data analysis, fractions, geometry, and measurement. The Canadian TIMSS-1995 data included 8,770 students from 385 schools. The student questionnaire completed by students when they took the TIMSS was the instrument used during this research. Canadian data was chosen by the researchers because of Canada's lack of a federal department of education. This feature of the Canadian educational system allows teachers to be autonomous and it was thought to allow for a wide variety of teaching techniques. The TIMSS-1995 used a stratified sampling procedure which first randomly selected the schools, then randomly selected the class within the school. The students were asked about the teaching practices within their classroom. The six approaches to teaching listed above were ranked by the students according to the frequency of the practice in their classroom. The rankings were represented on a scale consisting of almost always, pretty often, once in awhile, and never. Multilevel analysis with students nested within schools was used to rank the teaching approaches with the highest association with student achievement. School level and student level characteristics were controlled to allow for analysis of the relationship between teaching strategies and student achievement (Ma & Papanstasiou, 2006).

The study found that teachers explaining the rules and definitions had no detectable association with student achievement either at the student or the school level. A negative relationship was found between the teacher regularly discussing a practical or story problem related to everyday life to introduce the topic and student outcome. If this method was used infrequently, however, it had a positive relationship with achievement. When students worked in pairs or small groups when first learning a new topic, there was a negative association with student achievement. A negative relationship also existed between student achievement and the strategy introducing a new topic by asking the students what they already know about the topic. However, used infrequently this technique had a positive effect on student learning. Delivering a new topic to a student by having the student look at the textbook while the teacher talked about the subject matter had the weakest association with student achievement. The method with the strongest association between student achievement and how to introduce a new topic was the teacher presenting the topic for the first time in the form of an example. This was then followed up with students trying to solve an example related to the new topic. The students were given a new situation and had to use previously learned knowledge to solve the problem. This constructivist teaching strategy had a positive effect with all of the topics regardless of frequencies of use. Of the six methods for introducing a new topic in eighth grade mathematics, this method was the only one that had a positive effect on student learning when it was almost always used (Ma & Papanstasiou, 2006).

A different set of studies with similar goals examined the TIMSS-1999 data for best practices in pedagogy. The purpose of the study was to look at the relationship between learning activities used by teachers when introducing a new topic and science achievement of eighth grade Hong Kong and Japanese students on the TIMSS-1999. The same study was also performed for Chinese Taipei but the student achievement was specific to chemistry. The particular instructional activities that were investigated for each country were (a) teaching activities for new science topics, (b) homework activities, and (c) classroom instructional activities. The teaching activities for new science topics consisted of (a) having the teacher explain the rules and definitions, (b) discussing a practical or story problem related to everyday life, (c) working together in pairs or small groups on a problem project, (d) having the teacher ask the student what they know related to the new topic, (e) having the student look at the textbook while the teacher talks about it, and (f) trying to solve an example related to the new topic. The homework activities consisted of (a) students can start their homework in class, (b) students discuss their completed homework, (c) students check each other's homework, (d) the teacher gives students homework, and (e) the teacher checks homework. The classroom instructional activities used in the study that students were asked about in the questionnaire consisted of (a) students work on science projects, (b) students work from worksheets or textbooks on their own, (c) students use things from everyday life in solving science problems, (d) students work together in pairs or small groups, (e) the teacher gives a demonstration of an experiment, and (f) students do an experiment, or a practical investigation in class. These six instructional activities were presented to the students in the TIMSS-1999 student survey and they were asked to give the frequency each activity assigned in the classroom. The frequency scale used for each of the three activities was (a) never, (b) once in a while, (c) pretty often, and (d) almost always. The six instructional activities mentioned above were analyzed separately using jackknife variance estimation procedures along with multiple regression procedures to analyze the relationship between the instructional strategies and student scores on the TIMSS-1999 (House, 2002).

The sample size of eighth grade science students from Hong Kong who completed the necessary sections of the TIMSS-1999 used in this study was 6,031 students (House, 2002). The sample size of eighth grade science students from Japan who completed the necessary sections of the TIMSS-1999 to be analyzed in the study was 9,925 students (House, 2002). The sample size of eighth grade science students from Chinese Taipei who completed the necessary sections of the TIMSS-1999 used in this study was 5,312 students (House, 2002).

The first topic of the House studies to be reported was the relationship found between learning activities used in the classroom to introduce a new topic and student achievement on the TIMSS-1999. The results of the research showed a negative correlation between learning activities used when introducing a new topic and science achievement of eighth grade Hong Kong students when a teacher introduced a new science topic by the following methods: (a) having the teacher explain the rules and definitions (-0.122), (b) discussing a practical or story problem related to everyday life (-0.077), (c) having the teacher ask students what they know related to the new topic (-0.045), and (d) looking at the textbook while the teacher talks about it (-0.045). The positive correlation between learning activities and student achievement occurred when a teacher introduced a new science topic by having the students work together in small groups on a problem or project (0.089) (House, 2000).

The results of the research for Japanese eighth grade students showed a positive correlation between learning activities used by teachers when introducing a new topic and science achievement for the following learning activities: (a) having the teacher explain the rules and definitions (0.114), and (b) discussing a practical or story problem related to everyday life (0.045). The learning activities with a negative correlation were: (a) working together in small groups (-0.032), (b) having the teacher ask students what they know related to the new topic (-0.032), and (c) trying to solve an example related to the new topic (-0.032) (House, 2002).

The results of the research for Chinese Taipei eighth grade students showed a positive relationship between learning activities used by teachers when introducing a new topic and chemistry achievement for the following learning activities; (a) discussing a practical or story problem related to everyday life, (b) having the teacher explain the rules and definitions, (c) trying to solve an example related to the new topic, (d) looking at the textbook while the teacher talks about it, and (e) the teacher ask students what they know related to the new topic The learning activity with a negative correlation was working together in small groups (House, 2007).

Table 2.1 compares the correlation between learning activities used by teachers when introducing a new topic and science achievement. The correlations were shown relative in size to each other symbolically. The symbols have the following range: (a) +++ represents a correlation between 0.200 and 0.299, (b) ++ represents a correlation between 0.100 and 0.199, (c) + represents a correlation between 0.001 and 0.099, (d) 0 represents a correlation of 0.000, (e) - represents a correlation between -0.001 and- 0.099, (f) -- represents a correlation between -0.100 and -0.199, and (g) --- represents a correlation between -0.200 and -0.299.

The next House study to be investigated was the relationship between learning activities used in the classroom and student achievement on the TIMSS-1999. This was different from the previous study by reporting on learning activities being used in general and not just to introduce a topic.

The learning activities that showed a negative correlation with student achievement for the Hong Kong students were: (a) the students do an experiment or perform a practical investigation in class (-0.184), (b) the teacher gives a demonstration of an experiment (-0.164), (c) students work together in pairs or small groups (-0.071), and (d) students use things in everyday life in solving science problems (-0.045), (House, 2000). The one learning activity to have a positive correlation with student achievement was: (a) student’s work on science projects (0.110), (House, 2000).

The learning activities that showed a negative correlation with achievement by the Japanese students were: (a) student's work on science projects (-0.063), (b) students work from worksheets or textbooks on their own (-0.032). The learning activities to have a positive correlation with student achievement was: (a) the students do an experiment or perform a practical investigation in class (-0.184), (b) students use things in everyday life in solving science problems (0.100), (c) the teacher gives a demonstration of an experiment (0.105) and (d) students do an experiment or practical investigation in class (0.110), (House, 2002).

The learning activities to show a negative correlation with student achievement in chemistry for Chinese Taipei students were: (a) student's work together in pairs or small groups. The learning activities to have a positive correlation with student achievement in chemistry were: (a) students use things in everyday life in solving science problems, (b) students do an experiment or practical investigation in class, (c) students work on science projects, (d) the teacher gives a demonstration of an experiment, and (e) students work from worksheets or textbooks on their own (House, 2007).

Table 2.2 compares the correlation between learning activities used by teachers and science achievement on the TIMSS-1999. The correlations are shown relative in size to each other symbolically. The symbols have the following range: (a) +++ represents a correlation between 0.200 and 0.299, (b) ++ represents a correlation between 0.100 and 0.199, (c) + represents a correlation between 0.001 and 0.099, (d) 0 represents a correlation of 0.000, (e) - represents a correlation between -0.001 and- 0.099, (f) -- represents a correlation between -0.100 and -0.199, and (g) --- represents a correlation between -0.200 and -0.299.

Table 2.1

Correlation Strength of Learning Activities for New Science Topics and Science Achievement on TIMSS-1999

Learning activities students experience while learning a new science topic	Correlation
(House 2000) Overall science achievement - Hong Kong	
Working together in small groups on a problem set or project	+
Trying to solve an example related to the new topic	0
Looking at the textbook while the teacher talks about it	-
Having the teacher ask students what they know related to the new topic	-
Discussing a practical or story problem related to everyday life	-
Teacher explains the rules and definitions	--
(House 2002) Overall science achievement - Japan	
Teacher explains the rules and definitions	++
Discussing a practical or story problem related to everyday life	+
Looking at the textbook while the teacher talks about it	0
Working together in small groups on a problem set or project	-
Having the teacher ask students what they know related to the new topic	-
Trying to solve an example related to the new topic	-
(House 2007) Chemistry achievement – Chinese Taipei	
Discussing a practical or story problem related to everyday life	++
Teacher explains the rules and definitions	+
Trying to solve an example related to the new topic	+
Looking at the textbook while the teacher talks about it	+
Having the teacher ask students what they know related to the new topic	+
Working together in small groups on a problem set or project	--

Note. From “Relationships between instructional activities and science achievement of adolescent students in Hong Kong: Findings from the Third International Mathematics and Science Study (TIMSS),” by J.D. House, 2000, *International Journal of Instructional Media*, *27*(3), p 275. Copyright 2000 by J. Daniel House. Adapted with permission. “Relationships between instructional activities and science achievement of adolescent students in Japan,” by J.D. House, 2002, *International Journal of Instructional Media*, *29*(3), p 275. Copyright 2002 by J. Daniel House. Adapted with permission. “Relationships between self beliefs, instructional practices, and chemistry achievement of students in Chinese Taipei: Results from the TIMSS-1999 Assessment,” by J.D. House, 2007, *International Journal of Instructional Media*, *34*(2), p 187. Copyright 2007 by J. Daniel House. Adapted with permission.

The final House study in this set to be investigated was the relationship between homework activities used by the teacher and student achievement on the TIMSS-1999. This was different from the two previous studies by reporting on homework activities, not learning activities. The three same countries of Hong Kong, Japan and Chinese Taipei will be reported on with the same sample sizes and methods discussed previously.

The homework activities to show a positive correlation with student achievement for the Hong Kong students were: (a) students can begin their homework in class (0.105), and (b) students check each other's homework (0.045). There were no negative correlations between homework activities and student achievement for the Hong Kong students. The following homework activities showed no correlation with student achievement: (a) the teacher gives us homework, (b) the teacher check's the student's homework, and (c) students discuss their completed homework (House, 2000).

There were no homework activities to show a positive correlation with student achievement on the TIMSS-1999 for Japanese students. The following homework activities showed a negative correlation with student achievement: (a) students check each other's homework (-0.055), (b) students can begin their homework in class (-0.045), and (c) students discuss their completed homework (-0.032). The following homework activities showed no correlation with student achievement. the teacher gives us homework and, the teacher check's the student's homework (House, 2000).

Table 2.2

Correlation Strength Between Learning Activities and Science Achievement on TIMSS-1999

Learning activities students experience in their classroom	Correlation
<u>(House 2000) Overall science achievement - Hong Kong</u>	
Students work on science projects	++
Students work from worksheets or textbooks on their own	0
Students use things from everyday life in solving science problems	-
Students work together in pairs or small groups	-
The teacher gives a demonstration of an experiment	--
Students do an experiment or practical investigation in class	--
<u>(House 2002) Overall science achievement – Japan</u>	
Students do an experiment or practical investigation in class	++
The teacher gives a demonstration of an experiment	++
Students use things from everyday life in solving science problems	++
Students work together in pairs or small groups	0
Students work from worksheets or textbooks on their own	-
Students work on science projects	-
<u>(House 2007) Chemistry achievement – Chinese Taipei</u>	
Students use things from everyday life in solving science problems	++
Students do an experiment or practical investigation in class	+
Students work on science projects	+
The teacher gives a demonstration of an experiment	+
Students work from worksheets or textbooks on their own	0
Students work together in pairs or small groups	--

Note. From “Relationships between instructional activities and science achievement of adolescent students in Hong Kong: Findings from the Third International Mathematics and Science Study (TIMSS),” by J.D. House, 2000, *International Journal of Instructional Media, 27*(3), p 275. Copyright 2000 by J. Daniel House. Adapted with permission. “Relationships between instructional activities and science achievement of adolescent students in Japan,” by J.D. House, 2002, *International Journal of Instructional Media*, *29*(3), p 275. Copyright 2002 by J. Daniel House. Adapted with permission. “Relationships between self beliefs, instructional practices, and chemistry achievement of students in Chinese Taipei: Results from the TIMSS-1999 Assessment,” by J.D. House, 2007, *International Journal of Instructional Media*, *34*(2), p 187. Copyright 2007 by J. Daniel House. Adapted with permission.

The homework activities that showed a positive correlation with student achievement in chemistry for Chinese Taipei students were: (a) students discuss their completed homework, (b) the teacher gives us homework, and (c) the teacher checks the student's homework. The negative correlations between homework activities and student achievement in Chemistry for Chinese Taipei students were: (a) students check each other's homework and (b) students begin their homework in class (House, 2000).

Table 2.3 compares the correlation between homework activities used by teachers and science achievement on the TIMSS-1999. The correlations are shown symbolically as they exist relative in size to each other. The symbols have the following range: (a) +++ represents a correlation between 0.200 and 0.299, (b) ++ represents a correlation between 0.100 and 0.199, (c) + represents a correlation between 0.001 and 0.099, (d) 0 represents a correlation of 0.000, (e) - represents a correlation between -0.001 and- 0.099, (f) -- represents a correlation between -0.100 and -0.199, and (g) --- represents a correlation between -0.200 and -0.299.

Investigating the relationship between student beliefs and student achievement. House performed another group of studies which did not focus on the teacher beliefs and characteristics but focused more on the relationship between student characteristics and student achievement. Students included in one of these studies were the 5,312 Chinese Taipei students who completed all sections of the TIMSS-1999 student questionnaire necessary for use in the research. The covariate examined for effects on a student's chemistry achievement was student self beliefs. Student self beliefs were measured using two survey questions. The first question asked the students what was required to do well in science in their school. They were given the following four choices: (a) lots of natural talent, (b) good luck, (c) lots of hard work studying at home, and (d) to memorize the textbook or notes. The students were asked to rank their levels of agreement for each choice with the following Likert scale: (a) strongly disagree, (b) disagree, (c) agree, or (d) strongly agree. Students were also asked how they felt about studying science. They were asked to rank the following choices with the same Likert scale shown above: (a) I enjoy learning science, (b) science is boring, and (c) science is an easy subject. These variables were analyzed using jackknife variance estimation procedures along with multiple regression procedures to analyze the relationship between the variables and the student's chemistry achievement on the TIMSS-1999.

The results of this study show a significant negative correlation between the following Chinese Taipei student beliefs and chemistry achievement on the TIMSS-1999: (a) to do well in science at school, you need good luck, (b) science is boring, (c) to do well in science at school, you need to memorize the textbook or notes, and (d) science is an easy subject. A significant positive correlation was shown between the following student beliefs and chemistry achievement: (a) to do well in science at school, you need lots of natural talent, (b) to do well in science at school, you need lots of hard work studying at home, and (c) I enjoy learning science (House, 2007).

Table 2.3

Correlation Strength of Homework Activities and Science Achievement on TIMSS-1999

Homework activities and teaching practices	Correlation
(House 2000) Overall science achievement - Hong Kong	
Students begin their homework in class	++
Students check each other's homework	+
The teacher gives us homework	0
The teacher checks the student's homework	0
Students discuss their completed homework	0
(House 2002) Overall science achievement - Japan	
The teacher gives us homework	0
The teacher checks the student's homework	0
Students discuss their completed homework	-
Students begin their homework in class	-
Students check each other's homework	-
(House 2007) Chemistry achievement – Chinese Taipei	
Students discuss their completed homework	++
The teacher gives us homework	+
The teacher checks the student's homework	+
Students begin their homework in class	-
Students check each other's homework	-

Note. From "Relationships between instructional activities and science achievement of adolescent students in Hong Kong: Findings from the Third International Mathematics and Science Study (TIMSS)," by J.D. House, 2000, *International Journal of Instructional Media, 27*(3), p 275. Copyright 2000 by J. Daniel House. Adapted with permission. "Relationships between instructional activities and science achievement of adolescent students in Japan," by J.D. House, 2002, *International Journal of Instructional Media*, *29*(3), p 275. Copyright 2002 by J. Daniel House. Adapted with permission. "Relationships between self beliefs, instructional practices, and chemistry achievement of students in Chinese Taipei: Results from the TIMSS-1999 Assessment," by J.D. House, 2007, *International Journal of Instructional Media*, *34*(2), p 187. Copyright 2007 by J. Daniel House. Adapted with permission.

Table 2.4

Relationship Between Student Beliefs and Chemistry Achievement of Students in Chinese Taipei

Self belief variable	Relationship
To do well in science at school, students need lots of studying at home	+++
To do well in science at school, you need lots of natural talent	++
I enjoy learning science	++
Science is an easy subject	-
To do well in science at school, students need good luck	--
Science is boring	--
To do well in science at school, you need to memorize the textbook	---

Note. From "Relationships between self beliefs, instructional practices, and chemistry achievement of students in Chinese Taipei: Results from the TIMSS-1999 Assessment," by J.D. House, 2007, *International Journal of Instructional Media*, *34*(2), p 187. Copyright 2007 by J. Daniel House. Adapted with permission.

Table 2.4 compares the relationship between student beliefs and chemistry achievement of students in Chinese Taipei using the TIMSS-1999 data set. The relationships are shown symbolically relative in size to each other as mentioned earlier.

The effects of teacher characteristics on student achievement. Researchers have analyzed the TIMSS-2003 data to examine the relationships between teacher quality, opportunity gaps, national achievement, and achievement gaps. All 46 countries that participated in the TIMSS-2003 were used in this study. In particular, characteristics and variables from the United States will be analyzed. This study focused on the student and teacher questionnaires from eighth graders and their mathematics teachers as well as the scores received by the students. The TIMSS-2003 used a two-stage stratified cluster sample design. Schools were selected during the first stage and then the classroom with students was selected during the second stage. To be consistent high teacher quality was measured by the percentages of students taught by: (a) teachers with full certification, (b) teachers with a mathematics major, (c) teachers with a mathematics education major, (d) teachers with three or more years of teaching experience, and (e) teachers with full certification, a mathematics or mathematics education major, and three or more years of teaching experience. The opportunity gap is the percentage of low income students who were taught by highly qualified teachers compared to the percentage of high income students who were taught by highly qualified teachers. The achievement gap is the difference in the score of the low income students compared to the high income students. The statistical techniques for analysis were done by direct comparisons of percentages of low income and high income students being taught by highly qualified teachers. Multiple regression analysis was also done so that multiple variables could be compared at the same time (Akiba, LeTendre, & Scribner, 2007).

The results of this study showed that 60% of students in the United States were taught by highly qualified teachers. The average across all of the 46 countries from the TIMSS-2003 data was 62%. The United States had the tenth largest achievement gap and the fourth largest opportunity gap. The opportunity gap was fourteen percent in the United States and the international average was two and a half percent (Akiba et al., 2007).

The effects of student characteristics and beliefs on student achievement. The relationship between the parental, self and peer group influences on the attitude and achievement of high school seniors who have chosen to enroll in advanced science courses may give insight into how environmental characteristics affect student achievement. The four variables from the TIMSS-1995 used to measure the importance of science for the student were the importance of doing well in science for the: (a) student's mother, (b) student's father, (c) student's self, and (d) student's friends. The four variables that were used to measure science attitudes were whether the students liked: (a) physics, (b) chemistry, (c) biology, and (d) earth science. The last two variables used in this study were: (a) if the students reported that they usually had done well in science in the past and (b) the student's TIMSS advanced science score. The level of achievement for the students was taken from their score on the TIMSS advanced science score. The three countries analyzed in this study were Australia, Cypress, and the United States. The sample of student data that was used came from population three of the TIMSS-1995. These populations included students completing their final year of secondary school and also were taking advanced science and mathematics classes. In order to analyze multiple independent and dependent variables at the same time a structural equation model was used (Papanastasiou & Zembylas, 2004).

The results that were the same across all three countries showed a positive relationship between students who felt their abilities in science were high and their perceived importance of science as a subject. In Australia, students that were taking advanced science classes and achieved at a high level also had a positive attitude toward science. What also should be noted was that students who had a positive attitude toward science did not have a relationship with student achievement. Students from Cyprus did not show a relationship between their self-perceived abilities in science and their scores on the TIMSS. Cypriot science students did have a positive relationship with their attitude about science and their scores on the TIMSS. The data also showed that if a student scored high on the TIMSS it did not have a relationship with their attitude toward science. In the United States the relationship between the attitude toward science and the score on the TIMSS was a positive one (Papanastasiou & Zembylas, 2004).

Another study analyzed the relationship between the self beliefs of eighth grade students from Hong Kong and science as well as mathematics achievement on the TIMSS-1995. The sample consisted of 6,476 eighth grade students who completed all of the mathematics self-belief measures on the TIMSS-1995 student questionnaire and 6,411 eighth grade students who completed all of the science self-belief measures on the TIMSS-1995 student questionnaire. To measure the students' self beliefs in mathematics the student questionnaire asked the students what it takes to do well in mathematics class. The choices they had included: (a) lots of natural talent, (b) good luck, (c) lots of hard work studying at home, and (d) memorize the textbook or notes. The students were also asked about their attitude towards school mathematics achievement. The students' choices were: (a) I enjoy learning mathematics, (b) mathematics is boring, (c) mathematics is an easy subject, and (d) mathematics is important to everyone's life. For each of these choices the student had to rank how they felt about it using the following Likert scale: (a) strongly disagree, (b) disagree, (c) agree, or (d) strongly agree. The same questions and rankings were also asked for science content. The measures mentioned above were analyzed separately using jackknife variance estimation procedures along with multiple regression procedures to analyze the relationship between the self-beliefs and student scores on the TIMSS-1995. The TIMSS used a two-stage cluster design to randomly choose classes to take the TIMSS-1995. During the first stage of sampling the schools were chosen and during the second stage the classrooms were chosen. Multiple regression techniques were used simultaneously to find the relationship between each self-belief variable and the TIMSS-1995 scores (House, 2003a).

The results of the study show a significant negative relationship between the following Hong Kong student beliefs and mathematics achievement on the TIMSS-1995: (a) mathematics is boring (-0.207), and (b) to do well in science at school, you need to memorize the textbook or notes (-0.151). Also the results of the study show a significant positive relationship between the following Hong Kong student beliefs and mathematics achievement on the TIMSS-1995: (a) I enjoy learning mathematics (0.275), (b) mathematics is an easy subject (0.154), (c) mathematics is important to everyone's life (0.127), (d) to do well in mathematics at school, you need lots of natural talent (0.109), and (e) to do well in mathematics at school, you need lots of hard work studying at home (0.061). For the subject of science the same beliefs had different correlation values. The one significant negative relationship between Hong Kong student beliefs and science achievement on the TIMSS-1995 was that science is boring (-0.165). The results of the study also show a significant positive relationship between the following Hong Kong student beliefs and science achievement on the TIMSS-1995: (a) I enjoy learning science (0.187), (b) science is important to everyone's life (0.168), (c) to do well in science at school, you need lots of hard work studying at home (0.113), (d) to do well in science at school, you need lots of natural talent (0.089), and (e) science is an easy subject (0.057) (House, 2003a).

Relationships Between Covariates and Science Beliefs

It may be of interest to educators to research the relationships that exist between TIMSS covariates and a student's beliefs about science.

Investigating teaching activities effect on how students think of science. An additional study looked at how teaching pedagogy and classroom activities affected students in other ways besides the test scores they received on the TIMSS. The following research investigated the relationships between instructional strategies and student interest in science using data from the TIMSS-1999 for Japanese and U.S. eighth grade students. The study also compared the effectiveness of these strategies between Japan and the United States. The data analyzed for this study came from the TIMSS-1999 student questionnaire, in particular instructional activities, out of school activities, family characteristics, learning resources, student characteristics, and student achievement. The instructional activities consisted of the method a teacher used to introduce a new topic and typical classroom instructional activities. These activities were then related to how much a student enjoyed science. The choices the student had on the questionnaire were the same as the choices mentioned in previous studies that used the TIMSS-1999 data. The activities mentioned above were analyzed separately using jackknife variance estimation procedures along with multiple regression procedures to analyze the relationship between the instructional strategies and student scores on the TIMSS-1999. The sample consisted of 10,052 Japanese students and 9,916 United States students who fully completed the questionnaire measures regarding teaching activities. The sample also consisted of 10,086 Japanese students and 10,033 United States students who fully completed the questionnaire measures regarding activities used when learning new science topics (House, 2003b).

In Japan, students who reported higher levels of enjoyment for learning science were more likely to report having a teacher introduce a new topic by: (a) explaining rules and definitions (0.108), (b) trying to solve an example related to the new topic (0.112), (c) asking students what they know about the new topic (0.121), (d) working together in small groups on a problem or project (0.132), and (e) discussing a practical or story problem related to everyday life (0.146). The one teaching strategy for introducing a new topic that was uncorrelated with student enjoyment of learning science was looking at the textbook while the teacher talks about it (0.003). In the United States all six techniques a teacher used to introduce a new topic were positively correlated with student achievement, and the correlations were numerically higher than comparable ones from Japan: (a) looking at the textbook while the teacher talks about it (0.104), (b) working together in small groups on a problem or project (0.145), (c) discussing a practical or story problem related to everyday life (0.164), (d) asking students what they know about the new topic (0.188), (e) explaining rules and definitions (0.205), and (f) trying to solve an example related to the new topic (0.210). Japanese students who reported higher levels of enjoyment for learning science were more likely to report seven of the eight classroom instructional activities: (a) the teacher shows us how to do science problems (0.080), (b) we work on science projects (0.088), (c) we work from worksheets or textbooks on our own (0.095), (d) the teacher gives a demonstration of an experiment (0.113), (e) we work together in pairs or small groups (0.121), (f) we ourselves do an experiment or practical investigation in class (0.122), and (g) we use things from everyday life in solving science problems (0.185). The one classroom activity that was uncorrelated with Japanese student enjoyment for learning science was students use computers. In the United States, however, all eight classroom instructional strategies were positively correlated with the student's enjoyment of science. The correlations were stronger than the comparable Japanese correlations. These eight strategies along with their correlation values were: (a) students use computers (0.078), (b) students work from worksheets or textbooks on their own (0.096), (c) students work on science projects (0.165), (d) students work together in pairs or small groups (0.170), (e) the teacher gives a demonstration of an experiment (0.174), (f) students do an experiment or practical investigation in class (0.174), (g) students use things from everyday life in solving science problems (0.221), and (h) the teacher shows students how to do science problems (0.246) (House, 2003b).

Table 2.5 compares the correlation strength between learning activities for studying new science topics and student interest in science for Japan and the United States using TIMSS-1999 data. The correlations are shown symbolically relative in size to each other. The symbols have the following range: (a) +++ represents a correlation between 0.200 and 0.299, (b) ++ represents a correlation between 0.100 and 0.199, (c) + represents a correlation between 0.001 and 0.099, (d) 0 represents a correlation of 0.000, (e) - represents a correlation between -0.001 and- 0.099, (f) -- represents a correlation between -0.100 and -0.199, and (g) --- represents a correlation between -0.200 and -0.299.

House (2009) also investigated how various teaching strategies affected student interest in entering a career in science. The purpose of the study was designed to examine the relationships between teacher pedagogy and student interest in having a career in science. The sample of students used in this study was taken from eighth grade Korean students who participated in the TIMSS-2003. This group consisted of 5,125 Korean students who completed all of the questions from the TIMSS-2003 student survey regarding classroom instructional strategies that were examined in this study. The TIMSS-2003 used a two-stage stratified cluster sample design. Jackknife variance estimation procedures were used along with multiple regression procedures to analyze the relationship between teaching strategies and student interest in a science career. Schools were selected during the first stage and then the students were selected during the second stage. Initial stratification was made according to which province and type of community the student belonged. The second stratification was made by student gender within the schools. Special schools such as remote schools, special education schools, and sports schools were excluded from the sampling. This resulted in 149 schools participating in the TIMSS-2003 (House, 2009).

The eleven teaching strategies that were analyzed from the TIMSS-2003 student survey responses included: (a) students watch the teacher demonstrate an experiment or investigation, (b) students design or plan an experiment or investigation, (c) students conduct an experiment or investigation, (d) students work in small groups on an experiment or investigation, (e) students write explanations about what was observed and why it happened, (f) students relate what they are learning in science to their daily lives, (g) students present their work to the class, (h) students review their homework, (i) students listen to the teacher give a lecture-style presentation, (j) students work problems on their own, and (k) students begin their homework in class. For each of these teaching strategies the student was asked to rate the frequency of the teaching strategy observed in class using the following scale: (a) every, or almost every lesson, (b) about half the lessons, (c) some lessons, or (d) never. The students also answered a question about their level of interest in wanting a job in a science field using the following scale: (a) agree a lot, (b) agree a little, (c) disagree a little, or (d) disagree a lot. The mean and standard deviation for the frequency of each teaching strategy and the level of interest for a career in science was calculated with multiple regression analysis. The results showed a significant relationship between a student wanting to have a science career, and being in a classroom where the student reported either (a) we relate what we are learning in science to our daily lives, or (b) we work problems on our own, or we design or plan an experiment or investigation. Students in classrooms in which they watched the teacher demonstrate an experiment or investigation, or where students presented their work to the class were more likely to state interest in a science career. Being in a classroom where the student reported listening to the teacher give a lecture-style presentation was negatively correlated with interest in a science career. The remaining teaching strategies were uncorrelated with the main outcome of the study (House, 2009).

Table 2.6 compares the correlation strength between learning activities for studying new science topics and student interest in science for Japan and the United States using TIMSS-1999 data. The correlations are shown symbolically relative in size to each other. The symbols have the following range: (a) +++ represents a correlation between 0.200 and 0.299, (b) ++ represents a correlation between 0.100 and 0.199, (c) + represents a correlation between 0.001 and 0.099, (d) 0 represents a correlation of 0.000, (e) - represents a correlation between -0.001 and - 0.099, (f) -- represents a correlation between -0.100 and -0.199, and (g) --- represents a correlation between -0.200 and -0.299.

Table 2.5

Correlation Strength Between Learning Activities for Studying New Science Topics and Student Interest in Science for Japan and the United States Using TIMSS-1999 data

Teaching activities experienced when learning a new topic	Japan	United States
Having the teacher explain the rules and definitions	++	+++
Trying to solve an example related to the new topic	++	+++
Working together in small groups on a problem set or project	++	++
Teacher asks students what they know related to the new topic	++	++
Discussing a practical or story problem related to everyday life	++	++
Looking at the textbook while the teacher talks about it.	0	++

Note. From "Instructional activities and interest in science learning for adolescent students in Japan and the United States: Findings from the Third International Mathematics And Science Study (TIMSS)," by J.D. House, 2003, *International Journal of Instructional Media*, *30(4)*, p 429. Copyright 2003 by J. Daniel House. Adapted with permission.

Table 2.6

Correlation Strength Between Learning Activities and Student Interest in Science for Japan and the United States Using TIMSS-1999 Data

Learning Activities students experience in their classroom	Japan	United States
Students use things from everyday life in solving science problems	++	+++
Students work together in pairs or small groups	++	++
The teacher gives a demonstration of an experiment	++	++
Students do an experiment or practical investigation in class	++	++
Students work on science projects	+	++
Students work from worksheets or textbooks on their own	+	+

Note. From "Instructional activities and interest in science learning for adolescent students in Japan and the United States: Findings from the Third International Mathematics And Science Study (TIMSS)," by J.D. House, 2003, *International Journal of Instructional Media, 30(4),* p 429. Copyright 2003 by J. Daniel House. Adapted with permission.

An additional approach to investigating how schools and teachers affect student outcome on the eighth grade science portion of the TIMSS-1999 was investigated in a study using data from Turkish student achievement scores. The purpose of the study was to investigate if a difference of classroom activities and teaching strategies between high and low performing schools existed. The sample initially had 7,841 eighth grade Turkish students belonging to 204 schools, who had completed the TIMSS-1999 student questionnaire. In this study, the top twenty and bottom twenty performing schools were chosen, resulting in forty schools and 1,564 students. Performance was determined by the mean student science score on the science portion of the TIMSS-1999. The mean average of the 204 Turkish schools that took the TIMSS-1999 was 488. The high performing Turkish schools had a mean of 511 and the low performing Turkish schools had a mean of 365. Discriminant function analysis was used to find differences in classroom activities between the high and low achieving schools. Seventeen classroom activity variables from the student questionnaire were selected to be analyzed. Wilks' lambda and chi square tests were used to find if there were significant differences across the predictor variables. Then factor analysis was done to collapse twenty nine variables related to family background, attitudes, and classroom activities. A second discriminant function analysis was used to find any differences between low and high achieving Turkish schools regarding factor structures including: (a) student centered activities, (b) teacher centered activities, (c) technology use, (d) need to do well in science, (e) socioeconomic background, and (f) attitude toward science (Aypay, Erdogan, & Sozer, 2007).

The first analysis of the study found that ten of the seventeen independent variables related to classroom activities discriminated between low and high achieving schools. The five classroom activities that identified low performing schools were: (a) teacher checks homework (0.489), (b) students can begin their homework in class (0.484), (c) students are encouraged to work in pairs and small groups (0.476), (d) students are allowed to check each other's homework (0.468), and (e) when beginning a new topic in science, the students begin by looking at the textbook while the teacher talks about it (0.378). The five classroom activities that identified the high performing schools were: (a) students copy notes from the board (0.254), (b) when beginning a new topic in science, students begin by having the teacher explain the rules and definitions (0.244), (c) students are allowed to use the board (0.234), (d) teacher gives a demonstration of an experiment (0.171), and (e) when beginning a new topic in science, students begin by discussing a practical or story problem related to everyday life (0.071). The second discriminating analysis found six predictor variables that discriminated between a low or high achieving school: (a) the teacher preferred using student-centered activities in the classroom, (b) the students thought doing well in science was important, and (c) the teacher preferred using technology in the classroom predicted low performing schools, while (a) the teacher preferred using teacher centered activities in the classroom, (b) the student's relatively high socioeconomic background, and (c) the students having a positive attitude toward science predicted a high performing school (Aypay et al., 2007).

Relationships Between Covariates and Class Size

It may be of interest to educational policymakers to understand the relationships between TIMSS covariates and the number of students within a class.

The effects of class size on teaching strategies and student achievement. Educators are interested in how class size affects teaching strategies and student achievement because this is a variable that is easy to control. Pong and Pallas (2001) performed a study to research how class size affects teaching strategies across nine countries from the TIMSS-1995. They also analyzed the relationship between class size and eighth grade math student achievement in these nine countries: Australia, Canada, France, Germany, Hong Kong, Korea, Iceland, Singapore, and the United States (Pong & Pallas, 2001).

Of the nine countries that were chosen for this study, three were from English-speaking countries, three from Europe, and three from East Asia. These countries were also chosen for their wide range of class size across the countries and the wide range of educational systems. The data used from the TIMSS-1995 was restricted to eighth grade mathematics classes from the nine countries listed and the teacher linked to the class reported class size in the teacher survey. The number of classrooms used in the countries range from 91 in Iceland to 302 in Canada. The number of students from each country range from 1,281 to 6,594 (Pong & Pallas, 2001).

The researchers use a hierarchical linear modeling (HLM) statistical approach to analyze the data. This analysis was carried out in many stages for each country. These stages include an analysis of the variables listed in Table 2.7 at both the student level and classroom level. At the student level the control variables were student gender, parents' education level, number of books in the home, and the number of parents in the home. The distribution of the class size across the countries had a wide range. Iceland had the smallest average class size of 16.4 students and the East Asian countries had the largest average class sizes with a range of 35.5 students in Singapore to 49.5 students in Korea. The rest of the countries had an average class size of approximately 25 to 26 students. After controlling for the four variables - gender, parent's education, number of books, and number of parents - the countries which had a positive statistically significant relationship between class size and student achievement were, Australia, France, Germany, and Hong Kong. The United States was the only country which had a negative relationship between class size and student achievement, although it was very close to zero and was not statistically significant. All other countries had a positive relationship but were not statistically significant (Pong & Pallas, 2001).

Table 2.7

Variables Used by Pong & Pallas (2001) Using HLM Approach

Category	Variable
Gender	Boy or girl
Student SES	Parents' education
	Number of books
	Number of parents
Teacher characteristics	Teacher's age
	Teacher's gender
	Teaching experience
School characteristics	Total enrollment
	Urban center
Classroom characteristics	Class size
	Class SES
	Low achievement levels
Curriculum coverage	Number of topics taught
Instructional practice	Small group
	Individual work
	Whole class teaching
	Class discussion

Note. From "Class Size and Eighth-Grade Math Achievement in the United States and Abroad," by A. M. Pallas and S. L. Pong, 2001, *Educational Evaluation and Policy Analysis*, *23(3),* p. 251. Copyright 2001 by Aaron M. Pallas and Suet L. Pong. Adapted with permission.

How teaching strategies are affected by class size has been researched as well. This next study analyzed whether teaching methods had a relationship with classroom size for the TIMSS-1999. The researchers, Desimone, Smith, Baker, and Ueno (2005), look at the 38 countries participating in the study to see if a relationship between class size and conceptual and computational teaching approaches existed. The sample used for this study was the 6,171 eighth grade mathematics teacher surveys that were fully completed from the 38 countries that participated in the TIMSS-1999 (Desimone et al., 2005).

Two types of analyses were used to find the relationship between class size and teaching method. The first analysis consisted of creating a two-level model that predicted teaching methods depending on the class size. Next the correlations between class size and teaching methods within the country were compared for the United States, Japan, and Singapore. The multilevel analytic strategy of hierarchical linear modeling was used to simultaneously consider factors from multiple levels of analysis (Desimone et al., 2005).

In the United States it was found that a small positive relationship existed between increase of class size and use of conceptual teaching methods. For the high achieving countries of Japan and Singapore, there was no relationship between class size and teaching method (Desimone et al., 2005).

Relationship Between Curriculum and Education Reform

It may be of interest to educational policymakers to understand the relationships between the structure of the curriculum within a country and educational improvements that may have existed within a country.

Investigating curriculum effects. Educational policymakers are interested in the structure of the curriculum in a country. How educational reform will be implemented across the country will depend on how the curriculum in the country was structured. They would also be interested in how this structure affects the curriculum in individual schools. Schmidt and Prawat, (2006) explored the question of whether having a national curriculum in a country predicted if the curriculum would be homogeneous. The sample included the 37 countries that participated in the eighth grade mathematics section of the TIMSS-1995. The dependent variables in the study used to measure curriculum coherence were alignment and consistency of the curriculum. The alignment was measured by using the alignment between (a) content standards and textbooks, (b) textbooks and teacher coverage, and (c) content standards and teacher coverage. A least squares regression analysis was used with this data. Consistency was measured by the extent that a teacher gives priority or time allocation to a certain topic. The measurement for time allocation was a measure of how many standard deviations the particular teacher was from the mean. To determine the level of curriculum authority the TIMSS-1995 national level survey was used. From this instrument six areas were analyzed to decide on the country's level of curriculum authority. The six areas included: (a) mandates of overall goals for the educational system, (b) mandates of grade-level goals, (c) mandates regarding course offerings, (d) specification of course syllabi, (e) specification of examination content, and (f) the selection of textbooks. Other sources of information included 241 curriculum guides and documents from the 37 countries participating in the TIMSS-1995 as well as the questions from the TIMSS teacher questionnaire which discussed the number of lessons spent on eighth grade mathematics topics (Schmidt & Prawat, 2006).

The location of the institution that has authority over curriculum had very little effect over the alignment measures of content coverage. The regression coefficients relating location and alignment of curriculum throughout the system were as follows: (a) content standards and textbooks (-0.006), (b) textbooks and teacher coverage (-0.119), and (c) content standards and teacher coverage (-0.003). The consistency of time allocation by teachers on eighth grade mathematics topics shows that the only predictor variable that had a significant effect on time variability was prescribing exam content. When an exam topic was prescribed, the variability of time spent on a topic across the country went down. The location of the prescribing authority had no effect on this variable (Schmidt & Prawat, 2006).

Summary of Studies

A summary of the research may be useful to educators and policymakers when making decisions concerning educational reform.

Methodological Review. All of the studies discussed in this literature review were quantitative in nature and used multiple regression analysis as well as hierarchical linear modeling. The TIMSS consisted of a large data set, which allowed for a high degree of confidence that predicting trends in the sample data would hold true for the entire country. The studies were observational and correlational, making causal relationships difficult. For example, when analyzing teaching characteristics at the Turkish schools it was evident that certain types of teaching techniques occurred at the high achieving schools and not at the lower achieving schools. At first sight this may allow the reader to decide the teaching techniques at the higher achieving school must be superior. What wasn't considered was that it may be possible that if the strategies employed at the lower achieving schools were used in the higher achieving schools, the students might score even higher than the current situation. Also when comparisons were made across countries, other cultural factors may be causing the differences in the data that were not part of the TIMSS questionnaire. The TIMSS-1999 video study was a good example of cultural factors playing a role in the data. The lessons were of a wide variety and the analysis does not allow for direct comparison of how a specific topic was taught in each country. These teaching characteristics were not proved to be the cause of the difference in test scores between the higher achieving countries and the United States. It does help us to identify areas that can be researched further to further understand how the United States can be a high achieving country as well.

Gaps in the research. It was surprising that the amount of research completed from the TIMSS data over the years was relatively small. Most of the studies analyzed the data set from the years 1995 and 1999. A moderate number of studies used the 2003 data set and very few studies used the data from the TIMSS-2007. This lack of investigation in the later years leaves a very large gap in the analysis of the TIMSS data. In particular, analyzing relationships between United States student achievement and a wide variety of characteristics would seem to be interesting. Characteristics such as teacher strategies in the classroom, the relationships between class size and teaching strategies and how this relates to student achievement, as well as classroom activities and how to introduce a new topic have been analyzed in previous years but have not been analyzed using the 2007 data set. Comparing these co-relational results with results from previous years is also a worthwhile future area of study, as well as analyzing trends throughout the TIMSS data.

Chapter Summary

The research discussed in this literature review showed some of the different approaches researchers have taken in order to study the significance of the TIMSS and how it may be useful for educators and policymakers in improving the educational system of their country. The IEA has a stated goal of providing the TIMSS data to allow countries to analyze the data to improve their educational systems (Mullis et al., 2005). A discussion of cognitive psychology and how students learn best and what research stipulates as being effective may be a consideration of effective teaching.

The question of how to improve student achievement in the United States is a complicated one. Experts seem to disagree at many levels on how students will learn best. Experts struggle with deciding if a constructivist teaching strategy or a more didactic approach to instruction would be the most effective method of teaching to maximize student learning. It also comes into question whether it is the pedagogical approach of the teacher that matters most, or if it is the teacher qualification and background. Some researchers point out that it is not teachers at all that make the difference in student achievement, it is the students' environment in and away from school that influences the student scores the most.

Chapter 3: Research Design and Methodology

The purpose of this dissertation was to study three research questions that explore the relationships that may exist between class size, teaching strategies, and student achievement of eighth grade students in the United States. In order to discover these relationships, data from the TIMSS-2007 eighth grade science achievement scores and answers to student and teacher background questionnaires were used. The following chapter summarizes the research design and methodology for this quantitative study of the relationships between class size, student achievement, and teaching strategies reported in the TIMSS-2007. The chapter will include a general perspective of the study, the research content, the research participants, instruments used in data collection, procedures used in the study, a data analysis section, and a summary of the methodology used (Glatthorn & Joyner, 2005).

The TIMSS-2007 consisted of fifty participating countries and seven bench marking participants at the eighth grade level. A total of 241,613 students participated in the eighth grade TIMSS-2007 with 7,377 students from the United States. The number of United States schools sample was 300. Of these 300 schools, 13 were deemed ineligible due to either sampling flaws or not meeting standards set by the TIMSS. Another 48 schools chose not to participate in the study which left 239 schools in the United States that actually participated in the TIMSS-2007 (Olson et al., 2008).

General Perspective

The general perspective section of this study consists of descriptions of the methodology and research questions.

Methodology. A quantitative approach to the secondary analysis of the TIMSS data was used in this research study. Quantitative analysis of a large data set is helpful when trying to organize and make sense of many data points at one time (Creswell, 2009). Multivariate associations were analyzed to determine the relationships between teaching strategies and student achievement, class size and student achievement, as well as class size and teaching strategies used in the classroom. Finding the association between variables allowed the researcher to understand the relationship between the variables listed in the database and whether or not the relationship is meaningful and statistically significant (Patten, 2009). Due to the nested structure of the data hierarchical linear modeling was used to analyze these relationships (Raudenbush & Bryk, 2002)

Research Questions. The question of how to improve student achievement in science in the United States is a complicated one. Experts seem to disagree at many levels on how students will learn most effectively. In order to find effective ways for students to learn, research can be done to help with answering this dilemma. The research questions for this study that investigated the relationships of student achievement for the United States on the TIMSS-2007 compared to possible influencing factors were the following:

1. Is a student's class size associated with typical classroom pedagogical approaches to teach eighth grade science in the United States?

2. Do class size and typical classroom pedagogical approaches show a relationship with achievement scores for eighth grade science students in the United States?

3. What are the relationships discussed above for both suburban and urban schools?

It is important to note that the students were sampled and the teachers were not explicitly sampled. Instead, the teachers were given a questionnaire. The research questions used with this data can only generalize to the students and not the teachers or schools. Any teacher or school data used in this analysis will have to be merged to the student level. The investigation completed on the TIMSS data will be a student level analysis with teacher and school variables used as student attributes (Rutkowski, Leslie & Rutkowski, David, 2009).

Research Context

To help understand the TIMSS-2007 data, the International Association for the Evaluation of Educational Achievement (IEA) wrote five manuals that explained the characteristics of this international study. These five manuals provide a user guide, assessment framework report, technical report, two volumes of an encyclopedia, and two international reports.

The User Guide included a database showing student achievement on the TIMSS along with student, teacher, school, and curricular background for each of the 59 countries as well as the 8 benchmarking participants. The data showed the achievement and background of 433,785 students as well as the background of 46,770 teachers and 14,753 school principals. Only one curriculum questionnaire was answered for each country and was completed by the National Research Coordinator (NRC) designated by the country. For the United States, Patrick Gonzales from Boston College was designated as the NRC for the TIMSS-2007 (Foy & Olson, 2009).

Due to the complexity of this large database, the TIMSS devised a software program named the IDB Analyzer that helps the user examine the data with the correct statistical procedures and format. The User Guide explained how to use the analyzer properly as well as how to use the analyzer in conjunction with SPSS software. Four supplements were also included in the User Guide to help with further understanding of the details of the TIMSS data (Foy & Olson, 2009). Another manual that was helpful in understanding the setup of the TIMSS was the TIMSS-2007 Assessment Frameworks report.

The TIMSS-2007 Assessment Frameworks report has three frameworks consisting of the mathematics framework, science framework, and contextual framework. The mathematics and science frameworks presented the content and cognitive domains of these two subjects in both fourth and eighth grade. The contextual framework looked at the environment that a student encounters while in and out of school by use of student questionnaires. The purpose of these frameworks was to explain the assessment design of the TIMSS-2007.

Also explained within the assessment framework report was the curriculum model. The curriculum model for the TIMSS-2007 consisted of describing the intended curriculum, the implemented curriculum, and then the attained curriculum. The intended curriculum was represented by which topics the educational policymakers in a country have decided should be taught. The implemented curriculum was represented by what the teachers believed was taught. The attained curriculum was deduced from the successes and failures of the students answering questions on the TIMSS-2007 (Mullis et al., 2005). Knowing the reliability and validity of these achievement scores was addressed in the TIMSS-2007 Technical Report.

The TIMSS-2007 Technical Report had the purpose of documenting the methods and procedures the TIMSS-2007 followed in order to provide the world community with student data. Reliability and validity were a major concern of the TIMSS. The framework report described how these issues were handled while preparing to collect and then analyze data (Olson et al., 2008).

In order for researchers to better understand the educational system and policies of a country, the *TIMSS-2007 Encyclopedia: A Guide to Mathematics and Science Education Around the World* was prepared. This report also described the intended curriculum of each country for comparison with how students performed on those curriculum subjects. The TIMSS-2007 Encyclopedia allowed for meaningful comparisons between countries. Since most countries have very different educational systems, the differences are better understood with the information found within the encyclopedia (Mullis et al., 2008).

The two international reports published to present data to the public were the TIMSS-2007 International Science Report and the TIMSS-2007 International Mathematics Report. The data was set up to allow the reader to look at a single year data point as well as the trend for student achievement within a country over a period of time since 1995 (Martin et al., 2008).

These five reports can be used together to find the relationships between policy and curriculum expectations as well as the relationship between teaching strategies and student scores. It is the hope of the IEA that this information can be used by all educators to influence improved instruction and increased learning across the world (Martin et al., 2008).

Research Participants

The participants of the TIMSS-2007 were defined as the international desired target population. All students enrolled in the eighth year of formal schooling, counting from the first year of primary school, were part of this target population. United Nations Educational, Scientific and Cultural Organization (UNESCO) International Standard Classification definition was used to determine the first year of primary school. The students also had to have a minimum age of 13.5 years to be considered as part of the desired target population. In order to determine a representative sample from the country's population, a two-stage stratified cluster sample design was then used to randomize the student population being chosen for the TIMSS-2007 (Olson et al., 2008).

It is important to note that there were no school level exclusions of students in the United States, but the classroom level exclusions of students consisted of special education classes, disabled students within regular classes, and students unable to be tested in English. The United States has the highest overall exclusion rate of 7.9% except for Israel which has an extraordinarily high exclusion rate of 22.8%. All other countries except for Serbia (6.8% overall student exclusion rate) have an overall student exclusion percentage of 5.0% or less (Joncas, 2008a).

Instruments Used in Data Collection

A description of the instruments used in data collection for the TIMSS-2007 may be beneficial to the reader of TIMSS research to understand how data was gathered for analysis.

Eighth grade science and mathematics test. The TIMSS-2007 collected data from eighth grade science and mathematics students in fifty countries near the end of the country's school year. The TIMSS had a very large amount of questions to administer to the students. Because it would not be practical for each student to answer this number of questions, the TIMSS used a matrix sampling approach to allow for complete coverage of the desired topics. The eighth grade TIMSS consisted of 429 items, 215 items in mathematics and 214 items in science. Both the mathematics and science items were broken up into 14 blocks, which allowed for 14 test booklets in total. Each test booklet consisted of 2 blocks of mathematics and 2 blocks of science. This allowed for each student to only answer one seventh of the total number of questions and not all 429 items. To enable linking between booklets, each block appeared in two booklets (Olson et al., 2008).

The matrix sampling approach allowed for a large amount of data to be collected without burdening individual students with answering all of the possible questions. It is important to remember that because of this approach an individual student's performance cannot be analyzed. The data collected can allow researchers to make inferences about the distribution of student achievement in the country rather than that of the individual student (Foy, Galia, & Li, 2008).

Scaling method used in calculating eighth grade science achievement. Due to the complexities of the data collection methods used with the matrix sampling approach, the TIMSS-2007 used Item Response Theory (IRT) scaling to express student achievement. The IRT scaling used multiple imputation (plausible values) methods to calculate comparable student scores. This approach was used because students answered a subset of questions from the larger set of all possible questions. To further increase the reliability of the predicted student scores, the TIMSS scaling used a conditioning process that called for combining student responses to the questions they answered with information about the students' background (Foy et al., 2008).

Three different IRT models were used to calculate student achievement scores for the TIMSS-2007 assessment. For multiple choice questions, which were scored as correct or incorrect, a three-parameter model was used. A two-parameter model was used for constructed response questions that had only two possible response items and were also scored as correct or incorrect. These two forms of questions were considered dichotomous since they were scored as either correct or incorrect. A third IRT model was used with the constructed response questions that allowed for partial credit and were considered polytomous since they had more than two possible answers (Foy et al., 2008).

The scores reported by the TIMSS cannot be considered individual student test scores. They should be considered imputed scores that were conditional on the questions answered by the student and the student's background characteristics. These imputed scores were also referred to as plausible values. Since an imputation process was used to calculate student achievement, uncertainty in the achievement value existed. To show this error the TIMSS repeated the imputation process five times to arrive at five plausible values for each student. Analysis of the TIMSS plausible values will be run once for each plausible value, for a total of five times. The average of these five sets of data has been used as the best estimate for the analysis of student achievement (Foy & Olson, 2009).

The four questionnaires developed for the TIMSS-2007. The four questionnaires developed for the TIMSS-2007 were the (a) curriculum questionnaire, (b) school questionnaire, (c) teacher questionnaire, and (d) student questionnaire. The curriculum questionnaire collected information at the country level. One curriculum questionnaire was completed for each country with the main purpose of finding out the intended curriculum for the country. The school questionnaire was given to the school principal and asked for information about the school contexts and available resources for instruction. The teacher questionnaire was given to each sampled teacher and asked about their background and preparation for teaching. They were also asked about professional development activities they attended. The teachers were also asked about their teaching strategies and the topics and concepts taught to their students. The student questionnaire asked about the home and school environment that the sampled student encountered and their learning experiences in the classroom (Olson et al., 2008).

Measure of class size. The independent variable, class size, was measured at the second level of the three-level HLM being used in this study. The eighth grade science classroom teacher reported the number of students in the TIMSS class. This reported number was not the average class size for the school but the actual number of students in the TIMSS class. If a student was absent on the day the TIMSS exam was administered, there was not a makeup exam given unless the absent rate was larger than ten percent. In that case a makeup exam was given so that the absent rate for the exam was less than ten percent (Joncas, 2008b). In this study, class size was identified as CLASSIZE.

Measure of constructivist pedagogy. Constructivist pedagogy was defined in Chapter 1 of this study as a teaching approach that allows the student to build a scaffolding of understanding and comprehension from their classroom experiences (von Glasersfeld, 2001). This study utilized the data from the science teacher survey, which allowed for constructivist teaching strategies as the covariate of choice, not constructivist learning strategies. Question number seventeen in the eighth grade science teacher survey asked the teacher to rank how often they use a variety of teaching strategies. Three of these strategies could allow for students to learn from a constructivist approach in the classroom. The three teaching strategies were when a teacher asks students to a) design or plan experiments or investigations with variable identification DESGNEXP, b) conduct experiments or investigations with variable identification CONDEXP, and c) work together in small groups on experiments or investigations with variable identification SMALLGRP. These three strategies were combined with a variable identification of CONTEA.

The three strategies were measured on a four-point scale which was designed with the following values: 1) strategy is used in every or almost every lesson, 2) strategy is used in about half the lessons, 3) strategy is used in some lessons, and 4) strategy is never used (Olson et al., 2008). The combined variable CONTEA also had a four point spread similar to this Likert scale. The second and third strategies listed above have been considered to be similar strategies because they both include working on experiments or investigations. The Likert scale value for these two strategies were averaged and then added to the Likert scale value of the first strategy of having the student design an experiment or investigation. This allowed for the strategy of having the students design an experiment or investigation to be weighted at 50%, while the average of the other two strategies was weighted as the other 50%.

For purposes of calculating a Likert scale value for a combined constructivist teaching strategy variable, the Likert scale value for the teaching strategy of having students design an experiment was assigned the variable LDE. The Likert scale value for the teaching strategy of having students conduct experiments or investigations was assigned the variable LCE. The Likert scale value for the teaching strategy of having students work together in small groups on experiments or investigations was assigned the variable LSG. The equation for calculating the scale value for the combined constructivist teaching strategy variable CONTEA was;

$$\text{CONTEA Likert scale value} = ((\text{LDE}) + (\text{LCE}+\text{LSG})/2)/2. \tag{1}$$

The values of the new variable CONTEA were calculated in SPSS 16.0 and then used in the statistical software program HLM6.

Covariates in the model. The covariates for the three level hierarchical linear models being studied are listed in tables 3.1, 3.2 and 3.3. These covariates were chosen to be part of the model due to the influence the variable may have on the student outside of the school environment. If a measured variable involved school characteristics, it was not chosen to be part of the model. The Level 1 covariates describe characteristics of the student. The Level 2 covariates describe characteristics of the classroom teacher. The Level 3 covariates describe characteristics of the school.

Table 3.1

Description of Predictor Variables – Level 1

Predictor variables of student characteristics – Level 1	Variable ID	Variable Type
Student Gender	STUDGEN	Dichotomous
How often is English spoken at home?	LANGHOME	4 level scale
How many books are in the home?	BOOKHOME	5 level scale
Do you possess a calculator?	CALCHOME	Dichotomous
Do you possess a computer?	COMPHOME	Dichotomous
Do you possess a study desk?	DESKHOME	Dichotomous
Do you possess dictionary?	DICTHOME	Dichotomous
Do you possess an internet connection?	INTRHOME	Dichotomous
Highest level of education completed by a parent	PAREDLVL	7 level scale

Table 3.2

Description of Predictor Variables – Level 2

Predictor variables of teacher/classroom characteristics	Variable ID	Variable Type
How old are you?	TEACHAGE	6 level scale
Are you male or female?	TEACHGEN	Dichotomous
How many years of teaching experience do you have?	TEACHEXP	Number
Highest level of education you have completed.	TEACHEDL	6 level scale
Do you have a teaching license or certificate?	TEACHCER	Dichotomous

Table 3.3

Description of Predictor Variables – Level 3

Predictor variables of school characteristics	Variable ID	Variable Type
Type of community, population size	COMMSIZE	6 level scale
Percentage of students having a disadvantaged background	SCHDISS	4 level scale
Percentage of students having an affluent background	SCHAFFL	4 level scale

Procedures for Data Collection

Three research questions that used the TIMSS-2007 as the database for finding relationships were described in Chapter 1. The first question looked for a relationship between class size and teaching strategies while the next two questions analyzed the relationship between class size and student achievement and the relationship between teaching strategies with student achievement. These three research questions relied on proper statistical analysis of the TIMSS-2007 database.

Because the database involved was large and complex, a User Guide was supplied by the IEA which described how to analyze the TIMSS data properly. Before analyzing the data two issues that should have been considered were the TIMSS' multi-stage sample design and the use of imputed scores (also call plausible values). A random sample of schools from the participating country was selected in the first stage and then one or two intact fourth or eighth grade classes were selected in the second stage. In the United States two classes were randomly chosen from each sampled school. The resulting student sample from this type of randomization had sampling weights applied along with a re-sampling of data by using the jackknife technique. This approach allowed for estimation of sampling variances (Joncas, 2008a). This was a complicated procedure that was completed for the researcher with use of the International Database (IDB) Analyzer software developed by the IEA for specific use with the TIMSS database (Foy & Olson, 2009).

The IDB Analyzer is a plug-in software program for the statistical analysis software SPSS. The IDB Analyzer allowed the user to work with the TIMSS data in SPSS format without having to write programming code. The IDB analyzer took into account the sampling design used by the TIMSS when calculating statistics and their standard error. Whenever the IDB analyzer was used, it automatically ran the jackknife method on the data and took into account the five plausible values of student achievement (Foy & Olson, 2009).

The IDB analyzer had a merge module that allowed the researcher to merge the separate files within the TIMSS data set. This feature allowed for cross-country comparisons as well as the combination of data from different sources such as student, teacher, school, and country (Foy & Olson, 2009). For purposes of this dissertation only, the United States' eighth grade science data have been analyzed. Three levels of the nested data have been compared when teacher strategies were related to student achievement, relating class size to student achievement and relating class size to teacher strategies.

The next concern was to decide if three teaching strategies listed in the TIMSS data could be clustered into one constructivist teaching variable. A correlation matrix of teaching strategies listed in the TIMSS-2007 was calculated to test the prediction of certain teaching strategies clustering together with a high correlation matrix. This clustering showed a relationship between certain teaching strategies. The group of strategies that were clustered showed that a teacher using one of the grouped methods had a higher probability of using another teaching method within the group compared to a teaching strategy outside the group. The Appendix shows the results of the correlation matrix of teaching strategies for the eighth grade science TIMSS-2007 dataset.

The three teaching strategies that had a high correlation with each other were: (a) students design or plan an experiment or investigation, (b) students conduct an experiment or investigation, and (c) students work in small groups to conduct an experiment or investigation. These three teaching strategies were thought to be constructivist in nature since the students work on their own or in groups, building their knowledge upon previously learned knowledge. These three constructivist teaching strategies were combined into one variable labeled CONTEA. The next phase of data analysis was to address the research question outlined in Chapter 1 of this dissertation. The IDB analyzer was used to choose only the eighth grade science data from the United States. The three chosen teaching strategies were clustered into one composite variable called CONTEA to help capture the concept of a constructivist approach to teaching. The variable of class size and student achievement were not clustered and were used as reported in the TIMSS database.

After the variables were grouped and identified, the next analysis phase called for the use of a multilevel modeling technique to find the desired relationships. The student achievement scores listed in the TIMSS-2007 database were considered to be nested data. The students were nested within the classroom which was nested within the school. This implies that the students may have shared the same neighborhood, the same teachers, and the same classroom resources. This nesting means that students in these classes were more like each other than individual students chosen randomly from the total population. As a result, a bias towards these common characteristics now existed within the sample. This bias can be accounted for in the multilevel modeling technique, Hierarchical Linear Modeling (HLM). Traditional linear regression methods could not be used because a different regression model exists for each level. HLM addressed the challenges that the multilevel database presents (Kalaian & Kasim, 2007).

Weighting of the students was another challenge when working with the TIMSS data set. The TIMSS used a two-stage stratified cluster sample design. In stage one, schools were chosen based on the school size. Larger schools had a probability of being chosen proportional to the school size.   The second stage was a random choosing of two classrooms within a chosen school. All students within the chosen classroom were then given The TIMSS assessment (Rutkowski, Leslie & Rutkowski, David, 2009). The sample design of the TIMSS utilized stratification by school type (public, private), geographic location (northeast, southeast, mid-west, west), eight different categories for a location indicator relative to population of the area, and whether the school was above or below fifteen percent minority population. This allowed for a total of 128 implicit strata in the United States (Joncas 2008).

When analyzing the TIMSS data, weighting of the data was required to arrive at meaningful results. The weight given to a student was the reciprocal of the probability of the student to be chosen. If a student had a higher probability of being chosen then they would be given a larger weight when analyzing the data. In the TIMSS data there were five sets of weights: (a) total student weight, (b) student house weight, (c) student senate weight, (d) overall and subject teacher weight, and (e) school weight. Total student weight was the inverse of the probability of a student being chosen. This weight added up to the total student population in a country. Student house weight was proportional weighting for each student. The total house weight would not add up to the total population. For cross-country analysis student senate weight was used. Since some countries were much larger than others the weighting had to be adjusted to make sure the larger country data did not dominate the comparison. The senate weight was accomplished by making all of the student senate weights add up to 500 for each country. When analyzing teacher variables, the researcher used the overall teacher weight, which consisted of the student weight divided by the number of subject specific teachers a student had. The school level weight was the inverse of the probability of the school being chosen. The total school weight added up to the total number of schools in the given country (Rutkowski, Leslie & Rutkowski, David, 2009).

Careful consideration of the weighting of variables occurred when working with nested data that was analyzed at multiple levels. The software program HLM6 allowed for weighting of variables at the various levels. The total student weight was the inverse of the joint probability of a particular student being chosen from a particular class in a particular school. For calculating the overall student sampling weight at level one, the following formula was used:

$$\text{Total Student Weight}_{ijk} = (WF_k \times WA_k) \times (WF_j \times WA_j) \times (WF_i \times WA_i) \quad (2)$$

for student i ($i = 1,..., n_j$) in class j ($j = 1,..., n_k$) in school k ($k = 1,..., K$), where n_j is the number of students in class j, n_k is the number of classes in school k, and K is the total number of schools in the sample. WF is the weight factor, which is the inverse of the probability of the student, class, or school being chosen. WA is the weight adjustment for students, classes, or schools that did not participate in the survey. Multiplying *(WF_k x WA_k)* calculates the adjusted probability of selection for school *k*. This calculation is called the final school weight. Multiplying *(WF_j x WA_j)* calculates the adjusted conditional probability of selection for class *j*. This calculation is called the final class weight. Multiplying *(WF_i x WA_i)* calculates the adjusted conditional probability of selection for student *i*. This calculation is called the final student weight. When analyzing a three-level model that considers variance at the school, class, and student level, the final weights for each level should be calculated before analysis with HLM6 is started (Rutkowski, Leslie & Rutkowski, David, 2009).

Data Analysis

The TIMSS-2007 data for eighth grade science students from the United States had students nested within classrooms and classrooms nested within schools, which allowed for three possible areas of variation in student achievement. These variations could be accounted for by using the HLM technique. The nested characteristic of the United States TIMSS-2007 data required multilevel modeling at three levels. Level 1 was the individual or student level, Level 2 was the classroom level and Level 3 was the school level (Raudenbush & Bryk, 2002).

The simplest three-level models had no predictor variables across the three levels and were referred to as fully unconditional or the base model. This technique showed variation of the student achievement across the three different levels without taking into account any predictor variables. This preliminary step was then used for comparison purposes when we took into account predictor variables in the conditional models (Raudenbush & Bryk, 2002).

At the student level, the equation shows the variability among students. The model for eighth grade student achievement on the TIMSS-2007 was shown by a function consisting of the student's score equal to the class's mean score plus the deviation of the student's score from the class's mean score:

$$Y_{ijk} = \pi_{0jk} + e_{ijk} \tag{3}$$

where

Y_{ijk} achievement of student i in classroom j and school k;

π_{0jk} mean achievement of classroom j in school k; and

e_{ijk} deviation of student ijk's achievement from the classroom mean.

$i = 1, 2 \ldots n_{jk}$ children within classroom j in school k;

$j = 1, 2 \ldots J_k$ classrooms within school k; and

$k = 1, 2 \ldots K$ schools.

Level 2, which was the classroom level, showed the variability among classrooms. The model was a function that had the classroom mean achievement score equal to the school's mean achievement score plus the deviation of the classroom's achievement score and the school's mean achievement score.

$$\pi_{0jk} = \beta_{00k} + r_{0jk} \tag{4}$$

where

β_{00k} mean achievement score in school k;

r_{0jk} deviation of classroom *jk*'s achievement from the school mean.

Level 3, which was the school level, modeled the variability among schools. This third model was a function that had the school's mean achievement score equal to the mean achievement of all students from the United States plus the deviation of the school's mean achievement and the mean achievement of eighth grade students in the United States.

$$\beta_{00k} = \gamma_{000} + \mu_{00k} \quad (5)$$

where

γ_{000} mean achievement science score for eighth grade students in the United States;

μ_{00k} deviation of school *k*'s mean achievement score from the mean achievement score of students in the United States.

The unconditional three-level model separated the variability of the outcome Y_{ijk} into three sections: (Level 1) students in a classroom, σ^2, (Level 2) classrooms within a school, τ_π, and (Level 3) schools, τ_β (Raudenbush & Bryk, 2002).

The variance calculated in the unconditional model could be explained by measured variables at each level. These measured variables may have changed when moving from one level to the next. For example, a student's gender may have caused the student's score to move up or down depending on the teacher's characteristics, but the student's gender may have had a different effect on the student's achievement score when taking into account other classroom characteristics. In this situation, the regression coefficient associated with gender of the student may have been different depending on the characteristics of the classroom and teacher. Several conditional models could be tested with different predictor variables to identify factors that affect the achievement score of students (Raudenbush & Bryk, 2002).

In order to test the conditional models properly a base conditional model was required. Since the investigation of the independent effects of teaching strategies on student achievement was one of the primary interests of this dissertation, the base conditional model included these factors, but with no other predictor variables included. As new predictor variables were then added to the base conditional model the relationship with the predictor variable become evident (Erberber, 2009).

When answering the research question that investigated the student achievement associated with the science class size that the student was enrolled in and the teaching pedagogy in the classroom, a hierarchical linear modeling approach was beneficial to allowing accurate standard error values to be calculated. The following equation was the general Level 1 model that showed the student achievement plausible value 1 labeled STUDACH, as a function of student level predictor variables plus a random student level error. These calculations were required for each of the five plausible values for students. After the calculations were completed, the values calculated were then averaged to find the final results (Rutkowski, Leslie & Rutkowski, David, 2009).

$$\text{STUDACH}_{ijk} = \pi_{0jk} + \pi_{1jk} (\text{STUDGEN}_{ijk}) + \pi_{2jk} (\text{LANGHOME}_{ijk}) + \pi_{3jk} (\text{BOOKHOME}_{ijk}) + \pi_{4jk} (\text{CALCHOME}_{ijk}) + \pi_{5jk} (\text{COMPHOME}_{ijk}) + \pi_{6jk} (\text{DESKHOME}_{ijk}) + \pi_{7jk} (\text{DICTHOME}_{ijk}) + \pi_{8jk} (\text{INTRHOME}_{ijk}) + \pi_{9jk} (\text{PAREDLVL}_{ijk}) + e_{ijk} \quad (6)$$

where

$STUDACH_{ijk}$ was the achievement of child *i* in classroom *j* and school *k*;

π_{0jk} intercept for classroom *j* in school *k*;

π_{pjk} corresponding student level coefficient; and

e_{ijk} deviation of child *ijk*'s score from the predicted score.

The general Level 2 model was a function showing the classroom effect on student achievement.

$$\pi_{0jk} = \beta_{00k} + \beta_{01k} (TEACHAGE_{jk}) + \beta_{02k} (TEACHGEN_{jk}) + \beta_{03k} (TEACHEXP_{jk}) + \beta_{04k} (TEACHEDL_{jk}) + \beta_{05k} (TEACHCER_{jk}) + \beta_{06k} (CLASSIZE_{jk}) + \beta_{06k} (CONTEA_{jk}) + r_{0jk} \quad (7)$$

where

β_{00k} intercept for school *k* in showing the classroom effect π_{pjk};

β_{0qk} the corresponding classroom level coefficient; and

r_{0jk} deviation of classroom *jk*'s Level 1 coefficient, π_{0jk}, from the predicted value.

The general Level 3 model was a function showing the school effect on student achievement.

$$\beta_{00k} = \gamma_{000} + \gamma_{001} (COMMSIZE_{k}) + \gamma_{002}(SCHDISS_{k}) + \gamma_{003}(SCHAFFL_{k}) + u_{00k} \quad (8)$$

where

γ_{000} intercept term for the function;

γ_{00k} corresponding school level coefficient; and

u_{00k} deviation of school k's Level 2 coefficients, β_{pqk}, from the predicted value.

The mixed model equation then becomes

$$\text{STUDACH}_{ijk} = \gamma_{000} + \gamma_{001}(\text{COMMSIZE}_{k}) + \gamma_{002}(\text{SCHDISS}_{k}) + \gamma_{003}(\text{SCHAFFL}_{k}) + \gamma_{010}(\text{TEACHAGE}_{jk}) + \gamma_{020}(\text{TEACHGEN}_{jk}) + \gamma_{030}(\text{TEACHEXP}_{jk}) + \gamma_{040}(\text{TEACHEDL}_{jk}) + \gamma_{050}(\text{TEACHCER}_{jk}) + \gamma_{060}(\text{CLASSIZE}_{jk}) + \gamma_{070}(\text{CONTEA}_{jk}) + \gamma_{100}(\text{STUDGEN}_{ijk}) + \gamma_{200}(\text{LANGHOME}_{ijk}) + \gamma_{300}(\text{BOOKHOME}_{ijk}) + \gamma_{400}(\text{CALCHOME}_{ijk}) + \gamma_{500}(\text{COMPHOME}_{ijk}) + \gamma_{600}(\text{DESKHOME}_{ijk}) + \gamma_{700}(\text{DICTHOME}_{ijk}) + \gamma_{800}(\text{INTRHOME}_{ijk}) + \gamma_{900}(\text{PAREDLVL}_{ijk}) + r_{0jk} + u_{00k} + e_{ijk} \quad (9)$$

This mixed model equation can be simplified by labeling all of the Level 1 covariates as Level 1, all of the Level 2 covariates as Level 2 and all of the Level 3 covariates as Level 3. The result of these substitutions produces the following model:

$$\text{STUDACH}_{ijk} = \gamma_{000} + \gamma_{00k}(\text{Level 3}_{k}) + \gamma_{0j0}(\text{Level 2}_{jk}) + \gamma_{060}(\text{CLASSIZE}_{jk}) + \gamma_{070}(\text{CONTEA}_{jk}) + \gamma_{i00}(\text{Level 1}_{ijk}) + r_{0jk} + u_{00k} + e_{ijk}. \quad (10)$$

The second model shown represents the second part of research question two, which analyzed the relationship between class size and the use of constructivist teaching strategies. This new model was similar to the previous model discussed above except at Level 2 an interaction effect was used to capture any changes to the coefficient due to this effect. Level 1 and Level 3 in this second model are identical to the model discussed previously. Equation (11) represents the final mixed model, which includes the interaction effect of (CLASSIZE_{jk} * CONTEA_{jk}):

$$STUDACH_{ijk} = \gamma_{000} + \gamma_{00k} (\text{Level } 3_{\,k}) + \gamma_{0j0} (\text{Level } 2_{\,jk}) + \gamma_{060} (CLASSIZE_{\,jk}) + \gamma_{070} (CONTEA_{\,jk}) + \gamma_{080} (CLASSIZE_{\,jk} * CONTEA_{\,jk}) + \gamma_{i00} (\text{Level } 1_{\,ijk}) + r_{0jk} + u_{00k} + e_{ijk}. \quad (11)$$

Adding the interaction effect allowed for determining how much the dependent variable changed with the addition of ($CLASSIZE_{jk}$ * $CONTEA_{jk}$) into the model.

These same statistical strategies and methods were used when analyzing the same research questions to look at how the analysis changed with an urban environment for eighth grade science students in the United States.

Summary of the Methodology

This chapter presented the methodology for this study which examined the relationships between class size and teaching strategies, class size and student achievement, as well as the relationship between teaching strategies and student achievement using the TIMSS-2007 database. The manuals, reports, and user guides were introduced to help understand the research context of this dissertation. These documents outlined for the user the framework, background, and use of the TIMSS. The procedures used to develop the TIMSS-2007 database were described. In particular the sampling design and scaling methods used by the TIMSS were reported. The IEA IDB Analyzer software was also described. The use of the analyzer software was highly recommended in order to analyze data properly due to the complexity of the TIMSS database.

The last two sections of the chapter described the data analysis procedure for analyzing the research questions described earlier. The HLM model was chosen due to the nesting characteristics of the TIMSS data. The procedures required for this statistical analysis technique were described, as well as the mathematical models that were associated at each of the three levels of the data. The use of an unconditional model was presented initially. The unconditional model did not control for any predictor variables. In order to find the size of the effect of these predictor variables, a conditional model was discussed and presented. All data calculations and models run were accomplished with the use of SPSS 16.0 software.

To understand the relationship between the statistically significant control variables and the effect on student achievement, it was necessary to use the variables and values chart shown in Figure 3.1.

<u>Percentage of Students in School With Background\Economic Disadvantage - SCHDISS</u>

- 1 = "0 TO 10 PERCENT"
- 2 = "11 TO 25 PERCENT"
- 3 = "26 TO 50 PERCENT"
- 4 = "MORE THAN 50 PERCENT"
- 9 = "OMITTED"

<u>Percentage of Students in School With Background\Economic advantage - SCHAFFL</u>

- 1 = "0 TO 10 PERCENT"
- 2 = "11 TO 25 PERCENT"
- 3 = "26 TO 50 PERCENT"
- 4 = "MORE THAN 50 PERCENT"
- 9 = "OMITTED"

<u>Teacher Certificate - TEACHCER</u>

- 1 = "NO"
- 2 = "YES"
- 9 = “OMITTED”
- Coding was reversed in the original TIMSS-2007

<u>Student Gender - STUDGEN</u>

- 1 = "GIRL"
- 2 = "BOY"
- 9 = "OMITTED"

Frequency of Test Language Spoken Home - LANGHOME

- 1 = "NEVER"
- 2 = "SOMETIMES"
- 3 = "ALMOST ALWAYS"
- 4 = "ALWAYS"
- 9 = "OMITTED"
- Coding was reversed in the original TIMSS-2007

Number of books at Home - BOOKHOME

- 1 = "NONE OR VERY FEW (0 TO 10 BOOKS)"
- 2 = "ONE SHELF (11 TO 25 BOOKS)"
- 3 = "ONE BOOKCASE (26 TO 100 BOOKS)"
- 4 = "2 BOOKCASES (101 TO 200 BOOKS)"
- 5 = "3+ BOOKCASES (OVER 200 BOOKS)"
- 9 = "OMITTED"

Parent Education Level - PAREDLVL

- 1 = "LESS THAN LOWER-SECONDARY ED"
- 2 = "COMPLETED LOWER-SECONDARY ED"
- 3 = "COMPLETED UPPER-SECONDARY ED"
- 4 = "COMPLETED POST-SECONDARY ED BUT NOT UNIVERSITY"
- 5 = "UNIVERSITY DEGREE"
- 6 = "DO NOT KNOW"
- 9 = "OMITTED"
- Coding was reversed in the original TIMSS-2007

Student Designs an Experiment - DESGNEXP

Student Conducts an Experiment - CONDEXP

Student Works Small Groups - SMALLGRP

Average of the three variables above - CONTEA

- 1 = "NEVER"
- 2 = "ABOUT HALF THE LESSONS"
- 3 = "SOME LESSONS"
- 4 = "EVERY OR ALMOST EVERY LESSON"
- 9 = "OMITTED"
- Coding was reversed in the original TIMSS-2007

Community Size - COMMSIZE

- 1 = "3000 PEOPLE OR FEWER"
- 2 = "3001 TO 15000 PEOPLE"
- 3 = "15001 TO 50000 PEOPLE"
- 4 = "50001 TO 100000 PEOPLE"
- 5 = "100001 TO 500000 PEOPLE"
- 6 = "MORE THAN 500000 PEOPLE"
- 9 = "OMITTED"
- Coding was reversed in the original TIMSS-2007

Figure 3.1. Variables and values chart.

The predictor CONTEA was added to the base conditional model and the data results are shown in the following chart. The predictor CONTEA was a new predictor constructed from the predictors DESIGNEXP, CONDEXP and SMALLGRP. The possible values for these constructivist teaching strategy predictors were shown in Figure 3.1.

Some of the covariates listed in Figure 3.1 were originally coded by the TIMSS-2007 in reverse of the order shown above. These codes were changed for purposes of this study in order to allow for direct relationships between covariates to have positive coefficients and inverse relationships to show negative coefficients.

Chapter 4: Results

Introduction

The purpose of this study was to research how constructivist teaching strategies are associated with student achievement in the area of science on the eighth grade TIMSS-2007. These findings may allow educators to further understand the associations between teaching strategies and student achievement. Another analysis suggested by this study was to find the relationship between class size and student achievement and the implications it may have on teaching pedagogy. A facet of class size that was investigated included how the number of students in the classroom was associated with the teaching strategies used in the class. Educators may want to know if a school maximizes class size, can constructivist teaching still occur? Educators may also be interested in analyzing these relationships in order to have the most effective learning environment for students in the classroom.

The research questions for this study that investigated the relationships of student achievement for the United States on the TIMSS-2007 compared to possible influencing factors were the following:

Research Questions

1. What is the relationship between the use of constructivist teaching strategies and student achievement scores on the TIMSS-2007 for eighth grade science students in the United States?

2. How is class size related to both eighth grade science teachers' pedagogical approaches and eighth grade science students' achievement scores on the TIMSS 2007?

3. What are the relationships discussed above for both suburban and urban schools?

Data Analysis and Findings

The current study uses hierarchical linear modeling to analyze the TIMSS data at three levels. The models analyzed allow for understanding of relationships between covariates.

Base conditional model. The TIMSS-2007 data for eighth grade science students from the United States had students nested within classrooms and classrooms nested within schools, which allowed for three possible areas of variation in student achievement. These variations could be accounted for by analyzing the data with hierarchical linear modeling techniques. The nested characteristic of the United States TIMSS-2007 data required multilevel modeling at three levels. Level 1 was the individual or student level, Level 2 was the classroom level, and Level 3 was the school level (Raudenbush & Bryk, 2002).

The simplest three-level models have no predictors across the three levels and are referred to as the fully unconditional or the base model. This technique shows variation of the outcome variable of student achievement across the three different levels without taking into account any predictors. This preliminary step was needed to determine if sufficient variation exists to merit further investigation (Raudenbush & Bryk, 2002).

Testing the conditional models properly required a base conditional model with an outcome variable and control variables. Because the investigation of the independent association of teaching strategies on student achievement was one of the primary interests of this dissertation, the base conditional model included these factors, with no other predictors included. The new predictors were then added to the base conditional model to determine if there was a relationship between predictor and outcome (Erberber, 2009).

The administering of the TIMSS-2007 used a matrix sampling approach allowing for a large amount of data to be collected without burdening individual students with answering all of the possible questions. It is important to remember that because of this approach an individual student's performance could not be analyzed. The data collected allowed researchers to make inferences about the distribution of student achievement in the country rather than that of the individual student (Foy et al., 2008).

Due to the complexities of the data collection methods used with the matrix sampling approach, the TIMSS-2007 used Item Response Theory (IRT) scaling to express student achievement. The IRT scaling used multiple imputation (plausible values) methods to calculate comparable student scores. This approach was used because students answered a subset of questions from the larger set of all possible questions. To further increase the reliability of the predicted student scores, the TIMSS scaling used a conditioning process that called for combining student responses to the questions they answered with information about the students' background (Foy et al., 2008).

The scores reported by the TIMSS could not be considered individual student test scores. They should have been considered imputed scores that were conditional on the questions answered by the student and the student's background characteristics. These imputed scores were also referred to as plausible values. Because an imputation process was used to calculate student achievement, uncertainty in the achievement values existed.

To show this error, the TIMSS repeated the imputation process five times to arrive at five plausible values for each student. Analysis of the TIMSS plausible values were run once for each plausible value, for a total of five times. The average of these five sets of data has been used as the best estimate for the analysis of student achievement (Foy & Olson, 2009).

The base conditional model findings consisted of estimates for an intercept and control variables from the TIMSS-2007 data and questionnaire that characterized the student's home characteristics, community size, teacher characteristics as well as the economic status of the school.

Level 3 control variables school level. Of the set of school level predictors in the base conditional model, the only significant predictor of TIMSS achievement for eighth grade science students was the percentage of disadvantaged students within a school. Table 4.1 shows that each level change in the percentage of disadvantaged students in the school related to a decrease in a student's achievement by an average of 20.6 points. The three possible levels of the percentage of disadvantaged students were associated with a total decrease in an average student score of 61.8 points (0.74 SD). The number of standard deviations was calculated by dividing the shift in student score by the number of points for one standard deviation. One standard deviation on the science TIMSS scores for eighth grade students in the United States was 84 points (Martin et al., 2008).

Level 2 control variables - classroom level. Of the set of classroom level predictors in the base conditional model, the only significant predictor of TIMSS achievement for eighth grade science students included whether the teacher was certified. Table 4.1 shows that the score of a student on the science portion of the TIMSS-2007 was directly related with a teacher being certified in the subject being taught. This association reflected an average 21.2 point increase (0.25 SD) in student achievement when compared with students from a classroom with a teacher being certified in the subject being taught to a student in a classroom with a teacher not certified in the subject.

Level 1 control variables - student level. Of the set of student level predictors in the base conditional model, the significant predictors of TIMSS achievement for eighth grade science students were how often English was spoken in home, how many books are in the home, the education level of the parents, and student gender.

The achievement score of a student on the science portion of the TIMSS-2007 has been shown to be associated with how often the language of the TIMSS test was spoken in the home. This relationship suggested that the more often a family speaks English in the home the higher the student will achieve. Table 4.1 shows that each level change in the frequency of language spoken in the home related to a change in the student's score by an average of 6 points. The four possible levels of the frequency of language spoken in the home were associated with a total shift in student achievement of 24 points (0.29 SD).

The number of books in the home was a control variable that had a very strong association with student achievement on the science portion of the TIMSS. Table 4.1 shows that each level change in the number of books in the home related to a change in the student's achievement of 13 points. The four possible changes in levels for the number of books in the home was associated with a total shift in student score by an average of 52 points (0.62 SD).

The highest education level of a student's parent was shown to have an association on student achievement as well. This relationship suggested that the higher the education level of the parents the higher the student will achieve. Table 4.1 shows that each level change in the parent's education showed a change in the student's score of 2.2 points. The four possible levels of parent education were associated with a total shift in student achievement of 8.8 points (0.10 SD).

Student gender was also a statistically significant control variable that was associated with student achievement. This relationship suggested that girls will achieve18.5 points (0.22 SD) lower than boys on the TIMSS-2007 exam.

The TIMSS-2007 coded some of the variables from the student, teacher and school survey in reverse. As the frequency of these variables increased, the corresponding code decreased. This reverse coding may cause confusion with the interpretation of the liste tables. To help with the understanding of these tables negative signs attached to coefficients that have a direct relationship were changed to a positive value. The sign of the coefficient was also changed when an inverse relationship was shown as a positive value. The variables that were either a yes or no were coded with yes having a value of two and no having a value of one.

Table 4.1

Base Conditional Model Findings

Variable	Coefficient	95% CI		*df*	*p*
		Lower	Upper		
Intercept Predicted mean score	592.4 **	522.8	662.0	171	0.000
School-level variables					
% Disadvantaged	-20.6 **	-26.5	.-14.7	171	0.000
% Affluent	1.9	-3.4	7.2	171	0.492
Teacher-level variables					
Teacher Age	0.6	-4.3	5.5	338	0.826
Teacher Gender	0.0	-10.8	10.8	338	0.997
Teacher Experience	-0.1	-0.9	0.7	338	0.854
Teacher Education	-6.6	-17.4	4.2	338	0.227
Teacher Certified	21.2 **	6.5	35.9	338	0.005
Student-level variables					
Student gender	18.5 **	14.4	22.6	227	0.000
Language in home	6.0 **	2.5	9.5	322	0.001
Number of books in home	13.0 **	11.2	14.8	282	0.000
Calculator in home	8.1	-4.1	20.3	64	0.192
Computer in home	2.4	-7.6	12.4	53	0.646
Desk in home	-2.2	-7.7	3.3	49	0.438
Dictionary in home	-1.3	-9.3	6.7	32	0.759
Internet in home	3.4	-5.0	11.8	52	0.426
Parent education	2.2 **	3.4	1.0	128	0.000

Note: * p-value < 0.05, ** p-value < 0.01

After the base conditional model was analyzed predictor variables were added to see the affect of these additional variables in analyzing the previously mentioned research questions.

Research Question 1

What is the relationship between the use of constructivist teaching strategies and student achievement scores on the TIMSS-2007 for eighth grade science students in the United States?

The analysis of research question 1 has shown that in this high power study there was no evidence that a teacher who used a constructivist teaching approach in their classroom had students that performed better than teachers who did not use a constructivist teaching approach ($\beta = 1.1$, $p > .05$). Even if the analysis was statistically significant the effect would have been of negligible importance.

To verify that the covariate constructivist teaching was independent of the covariate certified teacher, an independent samples t-test was performed to compare the means of the covariates; frequency of constructivist teaching strategy and the teacher being certified or not. On average, certified teachers used constructivist teaching more often (μ=2.45, SE=0.008) than non-certified teachers (μ =2.48, SE=0.049). This difference was not significant $t(6225)=-0.687$, $p>>.05$, and the effect size was low $r=0.0087$. To further show that the frequency of constructivist teaching was independent of a teacher being certified and, was not statistically significant, the HLM model shown in Table 4.2 was run without the certified teacher covariate. The results of this model confirmed that the constructivist teaching strategy covariate was insignificant and not dependent on a teacher being certified.

Table 4.2

Base Conditional Model With the Addition of Constructivist Teaching Strategy

Variable	Coefficient	95% CI		*df*	*p*
		Lower	Upper		
Intercept Predicted mean score	588.9 **	513.8	664.0	171	0.000
School-level variables					
% Disadvantaged	-20.6 **	-26.5	.-14.7	171	0.000
% Affluent	1.9	-3.4	7.2	171	0.492
Teacher-level variables					
Teacher Age	0.5	-4.6	5.6	337	0.848
Teacher Gender	-0.1	-11.1	10.9	337	0.983
Teacher Experience	-0.1	-0.8	0.6	337	0.866
Teacher education	-6.5	-17.2	4.2	337	0.237
Teacher certified	21.0 **	-6.1	35.9	337	0.006
Constructivist Teaching	-1.1	-10.3	8.1	337	0.816
Student-level variables					
Student gender	18.5 **	14.4	22.6	227	0.000
Language in home	6.0 **	2.5	9.5	322	0.001
Number of books in home	13.0 **	11.2	14.8	283	0.000
Calculator in home	8.1	-4.0	20.2	64	0.192
Computer in home	2.4	-7.6	12.4	53	0.646
Desk in home	-2.2	-7.5	3.2	49	0.438
Dictionary in home	-1.3	-9.4	6.8	32	0.758
Internet in home	3.4	-5.0	11.8	52	0.426
Parent education	2.2 **	1.0	3.4	128	0.000

Note: * p-value < 0.05, ** p-value < 0.01.

Research Question 2

How is class size related to both eighth grade science teachers' pedagogical approaches and eighth grade science students' achievement scores on the TIMSS-2007?

The first part of research question 2 involved analyzing how class size relates to a teachers' pedagogical approach as reported by the TIMSS-2007 teacher questionnaire. An interaction effect between constructivist teaching and class size was introduced to find out if a relationship existed between a teacher using constructivist teaching strategies and the number of students in the class. The analysis of research question 2 has shown that there was no evidence that a teacher would increase or decrease their use of a constructivist teaching approach as the classroom size changed ($\beta = 0.1$, $p > .05$). Even if the analysis was statistically significant, the effect would have been of negligible importance.

The second part of research question 2 investigated how the number of students in a classroom related to student achievement. The analysis of part 2 of research question 2 has shown that, in this high power study, there was no evidence that the class size a student experiences will be related to their achievement on the science section of the TIMSS-2007 ($\beta = 0.0$, $p > .05$). Even if the analysis was statistically significant, the effect would have been of negligible importance.

Table 4.3

Base Conditional Model With the Addition of Constructivist Teaching Strategy, Class Size and Interaction Effect

Variable	Coefficient	95% CI		*df*	*p*
		Lower	Upper		
Intercept Predicted mean score	584.4 **	508.2	660.6	176	0.000
School-level variables					
% Disadvantaged	-20.9 **	-26.6	.-15.2	176	0.000
% Affluent	1.3	-4.0	6.6	176	0.628
Teacher-level variables					
Teacher Age	0.6	-4.5	5.7	344	0.832
Teacher Gender	1..0	-10.0	12.0	344	0.863
Teacher Experience	-0.1	-0.8	0.6	344	0.805
Teacher education	-5.3	-16.3	5.7	344	0.346
Teacher certified	20.0 **	5.5	34.5	344	0.008
Class Size	0.0	-0.4	0.4	344	0.913
Constructivist Teach	-0.1	-9.1	8.9	344	0.982
Interaction effect	-0.1	-0.7	0.5	344	0.864
Student-level variables					
Student gender	18.3 **	14.2	22.4	149	0.000
Language in home	6.2 **	2.8	9.6	247	0.001
Number of books in home	12.9 **	11.1	14.7	344	0.000
Calculator in home	7.6	-4.4	19.6	68	0.192
Computer in home	1.8	-7.8	11.4	58	0.646
Desk in home	-1.8	-7.1	3.5	58	0.438
Dictionary in home	-1.4	-9.4	6.6	31	0.758
Internet in home	4.1	-3.9	12.1	87	0.426
Parent education	2.3 **	1.1	3.5	127	0.000

Note: * p-value < 0.05, ** p-value < 0.01.

Table 4.4

Base Conditional Model With the Addition of Class Size

Variable	Coefficient	95% CI		*df*	*p*
		Lower	Upper		
Intercept Predicted mean score	593.0 **	523.6	662.4	171	0.000
School-level variables					
% Disadvantaged	-20.6 **	-26.5	.-14.7	171	0.000
% Affluent	1.9	-3.4	7.2	171	0.484
Teacher-level variables					
Teacher Age	0.5	-4.6	5.6	337	0.845
Teacher Gender	-0.1	-10.9	10.8	337	0.995
Teacher Experience	-0.1	-0.8	0.6	337	0.866
Teacher education	-6.5	-17.4	4.2	337	0.235
Teacher certified	21.0 **	6.6	36.0	337	0.005
Class Size	0.0	-0.4	0.4	337	0.914
Student-level variables					
Student gender	18.5 **	14.4	22.6	227	0.000
Language in home	6.0 **	2.5	9.5	319	0.001
Number of books in home	13.0 **	11.2	14.8	287	0.000
Calculator in home	8.1	-4.0	20.2	64	0.192
Computer in home	2.4	-7.7	12.4	53	0.646
Desk in home	-2.2	-7.6	3.2	49	0.438
Dictionary in home	-1.3	-9.4	6.8	32	0.759
Internet in home	3.4	-5.0	11.8	52	0.426
Parent education	2.2 **	1.0	3.4	127	0.000

Note: * p-value < 0.05, ** p-value < 0.01.

Research Question 3

What are the relationships discussed above for both suburban and urban schools?

Research question 3 was an investigation into how research question 1 and 2 would change when controlling for the size of the community surrounding the school. Before interpreting the findings it was important to note that the value of the community size was reported by the school principal. The principal was asked how many people live in the city, town, or area where the school was located. The principal may or may not have interpreted this question the same as the rest of the principals completing the survey.

The findings for research question 3 were almost identical to the findings for research questions 1 and 2, except for a few differences. One of the differences to note was that the teacher being certified was still significant when controlling for community size but the p-value has increased by a substantial amount. The other noteworthy variation was that the community size variable itself was significant ($p < 0.05$) with coefficient values of 4.8 or 4.9.

Summary of Findings

In summary, the findings suggest that constructivist teaching strategies did not have an association with student achievement on the science portion of the TIMSS-2007. The findings also suggest that a relationship did not exist between classroom size and the tendency for a teacher to use a constructivist approach in the classroom. A finding that may have implications for policy-makers to consider was the association between class size and student performance. The analysis has shown that a relationship did not exist between class size and student achievement on the science portion of the TIMSS-2007.

The predictor variable community size had an inverse relationship with student achievement. As the population of the surrounding community of the school decreases it was associated with an increase in student achievement. It should be noted that the population of the surrounding community was reported by the principal of the school and may not be consistent among principals. One principal may have considered the community to consist of the surrounding town or city while another principal may have considered the population of the school district as the surrounding community. The inconsistency that may have occurred across all of the principals did not allow for a valid measurement of deciding if a school was in an urban or suburban setting. When interpreting the data for research question 3, the variable community size was considered to be invalid for measuring the community size.

Summary of Secondary Findings

The results of the secondary findings suggest that low performing students in the United States would perform at a higher level if they were able to attend more affluent schools, with properly certified teachers and a home life that included a large number of books and a high frequency of the English language spoken in the home. Having parents with a high level of education did have an association with improved performance, but not as much as may have been expected. A finding of concern for the United States was the relationship between student gender and TIMSS achievement. The results of this analysis have suggested that boys were much more likely to score higher on the science portion of the TIMSS than girls.

Conclusion

These factors associated with student achievement and class size do not have easy solutions. Trying to change the poverty level of a school or the number of books in the home or the frequency of the English language being spoken in the home would require a major social movement that the United States does not seem to be ready for. The classroom characteristic of having highly qualified science teachers in every classroom has a direct relationship with student achievement, but policymakers have to decide if costs will outweigh the benefits. The factor of student gender is a complicated situation and does not have an easy solution. The established long term trend of girls scoring lower on mathematics and science exams is a reflection of the educational culture that currently exists in the United States. All of these factors associated with student achievement were even more complicated when they were taken together as a whole picture of what improvements should be made.

Despite the limitations of this type of cross-sectional study, this dissertation provides preliminary evidence for policymakers on how to combat low achievement on the TIMSS-2007 and other educational disparities in general. For example, the findings of this study may serve as a basis for using highly qualified teachers with larger class sizes, or redistricting of school districts to decrease the percentage of impoverished students in the school, or possibly the implementation of a tutoring program to help families increase the frequency of English spoken in the home. These types of programs come with difficulties and cultural implications that policymakers may find prohibitive, but if these types of programs provide empirical evidence about the effects of the intervention, a large scale program may be started.

These examples show the enormous challenge that exists when trying to change and improve educational practices in the United States. Monumental socio-economic changes will have to occur in order to substantially raise educational achievement. The current environment of allowing politicians to arbitrarily decide on how children should be educated does not allow for a systematic approach for improvement.

Chapter four has reported the findings of the statistical analysis of the three research questions presented in chapter one. Chapter five will further discuss these findings and summarize the entire study. An overview of the problem will be presented and major findings will be revealed and discussed. A concluding section will propose implications for action and recommendations for further research.

Chapter 5: Summary and Discussion

Introduction

The purpose of this study was to find the relationships that existed between student achievement on the TIMSS-2007 in the area of eighth grade science and factors that may have influenced this achievement. Understanding which factors have the most direct associations with student achievement may inform educational policymakers who seek to elevate science achievement of students in the United States.

Two of the relationships this quantitative study revealed were the association between constructivist teaching strategies and eighth grade student achievement on the science portion of the TIMSS-2007, as well as the association between the number of students in a class and eighth grade student achievement on the science portion of the TIMSS-2007. The relationship between the frequency of constructivist teaching strategies and the number of students in the classroom was also investigated. Lastly, these same associations were analyzed again with the size of the community as reported by the principal included as a predictor variable. These findings were considered in the context of the current educational environment, and the implications of the results for decision making by educational policymakers will be considered. A reflection of how the results compare to the current professional practice that occurs in school districts and how the findings may influence these strategies will be discussed.

This chapter was organized under five major headings, which include: (a) Introduction; (b) Implications of findings; (c) Limitations; (d) Recommendations; (e) Conclusion.

Implications of Findings

The research questions for this study investigated the relationship between U.S. eighth grade student achievement on the TIMSS-2007 and possible influencing factors. The focus of the study was to investigate any associations that may have occurred between student achievement, constructivist teaching strategies and class size. These associations were investigated with the following research questions in mind:

1. What is the relationship between the use of constructivist teaching strategies and student achievement scores on the TIMSS-2007 for eighth grade science students in the United States?

2. How is class size related to both eighth grade science teachers' pedagogical approaches and eighth grade science students' achievement scores on the TIMSS 2007?

3. What are the relationships discussed above for both suburban and urban schools?

Research question 1, the association between student achievement and constructivist teaching. The results of this study have shown that after controlling for a large number of student and school demographics, the use of a constructivist teaching strategy had no association with eighth grade student performance for the science section of the TIMSS-2007. Even if the analysis had been statistically significant the effect would have been of negligible importance. This finding may have important implications for science teachers who are following the current trend occurring across the United

States of science teachers introducing more constructivist teaching approaches in their classroom.

The results of this study call into question the findings reported in previous TIMSS research studies indicating that constructivist teaching approaches used in the classroom were found to be significant and were directly associated with eighth grade student achievement on the science portion of the TIMSS. It has been reported that the teaching strategies of having students conduct an experiment during class and also having students working in small groups was significant and was associated with an improvement in science achievement on the TIMSS-2007 (House, 2011). The strategy of having students design their own experiment was also found to be significant by this study and was associated with a decrease in student achievement (House, 2011).

In the current study, it was found that these three constructivist teaching strategies were found to not be significant, contradicting the House study. The difference in the findings of these two studies was due to the statistical analysis technique used in each study. The contradicting results were due to the use of multiple regression analysis in the House 2011 study compared to hierarchical linear modeling (HLM) used in the current study. These two approaches will typically yield different results when nested data is analyzed because HLM calculates a more accurate effect size since this technique controls for individual level, classroom level and school level variables at the same time, while multiple regression analysis controls for all variables at only one level (Rethinam, Pyke, & Lynch, 2008).

Another difference between these two studies was the predictor variables used in the analysis. The House study performed a multiple regression analysis, which used student achievement as the dependent variable. The predictor variables used in the regression equation consisted of the following teaching strategies reported by students surveyed in the TIMSS: (a) we make observations and describe what we see, (b) we watch the teacher demonstrate an experiment or investigation, (c) we design or plan an experiment or investigation, (d) we conduct an experiment or investigation, (e) we work in small groups on an experiment or investigation, (f) we read our science textbooks and other resource materials, (g) we memorize science facts and principles, (h) we use scientific facts and principles, (i) we use scientific formulas and laws to solve problems, (j) we give explanations about what we are studying, (k) we relate what we are learning in science to our daily lives, (l) we review our homework, (m) we listen to the teacher give a lecture style presentation, (n) we work problems on our own, and (o) we begin our homework in class. The multiple regression analysis also included the following science beliefs: (a) I usually do well in science, (b) science is more difficult for me than many of my classmates, (c) I enjoy learning science, (d) science is not one of my strengths, (e) I learn things quickly in science, and (f) science is boring. The last set of predictor variables for students in the United States analyzed with the multiple regression technique was focused on the following computer activities: (a) use a computer at home, (b) use a computer at school, (c) use a computer elsewhere, (d) use a computer for school work in science, (e) use the internet before or after school, and (f) play computer games before or after school. The beta coefficient (slope) of each predictor variable was then reported (House, 2011).

The current study used HLM to analyze relationships between student achievement and predictor variables at the school, classroom (teacher) and student level.

At the school level, the predictor variables consisted of the percent of affluent and disadvantaged students in the school. At the classroom level the predictor variables used in the HLM study consisted of: (a) frequency of use of three constructivist teaching strategies, (b) teacher age, (c) teacher gender, (d) teacher experience, (e) teacher education level, and (f) is the teacher certified? The student level predictor variables consisted of student characteristics outside the classroom influence, which were: (a) student gender, (b) frequency of English spoken in the home, (c) number of books in the home, (d) was there a calculator in the home, (e) was there a computer in the home, (f) was there a desk in the home, (g) was there a dictionary in the home, (h) was there internet in the home, and (i) what is the education level of the parents? The coefficient for each predictor variable was then reported and the strength of associations between these variables and student achievement was determined.

The third area for comparison between the two studies was the 95% confidence interval for the coefficients of the constructivist teaching strategies. The intervals for the three constructivist teaching strategies for the multiple regression study were calculated as the following; (a) we design or plan an experiment or investigation (-18.6,-10.6), (b) we conduct an experiment or investigation (10.4, 18.5), (c) we work in small groups on an experiment or investigation (0.5, 18.2). In the current study, these three constructivist teaching strategies were combined to form one constructivist teaching strategy which had a 95% confidence interval of (-8.1, 10.3). In order to make a direct comparison the three constructivist teaching strategies were also analyzed separately with HLM using all of the same predictor variables mentioned previously. The 95% confidence intervals for this analysis reported the following: (a) we design or plan an experiment or investigation

(-3.4, 14.0), (b) we conduct an experiment or investigation (-9.8, 9.9), and (c) we work in small groups on an experiment or investigation (-14.0, 5.1). The comparison between the confidence intervals for these two studies has shown the multiple regression study consisted of intervals that have a positive or negative impact, while the HLM study found each of the constructivist teaching strategies spanning across a coefficient value of zero. The multiple regression study revealed the constructivist teaching strategies to be significant and had either a negative or positive impact on the student achievement value. The HLM study revealed the constructivist teaching strategies to not be significant, and if each strategy was significant it would not have a relationship with student achievement.

These differences in results between the two studies can be confusing for educators and policymakers. When the researcher ignores the nested structure of the data and uses multiple regressions for analysis at the student level, it can result in an estimated standard error that is too small. A standard error that is too small can lead to an insignificant result being reported as significant, which is a Type I error (Raudenbush & Bryk, 1988). Multi-level modeling provides the researcher with an alternative to multiple regressions that allows for data to be analyzed simultaneously at multiple levels (Raudenbush & Bryk, 2002). Understanding the preferred method of analyzing multi-level data can help policymakers to make decisions that are effective in producing improved student achievement.

The current study has shown results that do not support the use of constructivist teaching strategies to improve student achievement in science. The findings reveal that constructivist teaching strategies did not improve or decrease student achievement on the eighth grade science portion of the TIMSS-2007. These results imply that teachers should not be forced to use constructivist teaching strategies in the classroom. The findings suggest that educational policy set at the local and national level should allow teachers to have free reign in deciding what teaching strategy will work best in the classroom.

The two most recent national educational policies that have been implemented in the United States were No Child Left Behind (NCLB) and Race to the Top. Both of these policies state that educators need to use research based teaching methods to improve student learning. The NCLB policy goes further to state that schools should not only use data based research to improve student achievement, but should also reject unproven fads (*No Child Left Behind The Facts About Science Achievement.*, 2004). In this case the unproven fad that needs to be rejected seems to be the exclusive use of constructivist teaching strategies in the classroom. Race to the Top has the improvement of student learning as a top priority as well and calls for providing teachers with data to guide instruction decisions. This policy does not dictate specific teaching strategies but calls for the improvement of teacher effectiveness by studying research and the analysis of longitudinal student data (*Race to the Top Executive Summary*, 2009). Neither of these policies suggested constructivism as a preferred teaching strategy, and both went further to insist that educators use student data before making decisions on effective teaching strategies (*No Child Left Behind Act of 2001*, 2002a)(*Race to the Top Executive Summary*, 2009). These stated policies agree with this study's findings that constructivist teaching strategy was not a preferred teaching method to be used exclusively in the science classroom. These policies agreed with the implication that teachers should be given free reign in deciding what pedagogical approach to use. Both policies state that data should be used when a teacher decides on what teaching strategy will be most effective.

These two policies state that teachers should analyze student data to make informed decisions about instruction. What was missing from this discussion was the idea that students, teachers and principals in United States schools were not randomized. Teachers will not be able to look at this data and make informed decisions unless the nested structure of the data was taken into account, and a random sample of schools and classrooms were analyzed with the same procedures followed by the TIMSS. Unfortunately, neither policy mentions this aspect of data analysis and gives the responsibility of data analysis to the teachers who mostly have not been trained in multi-level analysis techniques. This situation may allow for the misinterpretation of data and the incorrect conclusions about effective teaching strategies being drawn.

Research question 2 association between class size and use of constructivist teaching. The results of this study have also found the number of students in a classroom had no association with the frequency of constructivist teaching used in the classroom. This finding implies that a teacher in the United States was just as likely to use a constructivist teaching strategy whether they have a large or small number of students in their class. This finding also implies that a teacher did not take into consideration the class size when they decided if they would be using a constructivist approach to teaching in the classroom.

It was also reported by the Pong and Pallas (2001) study that class size was not associated with choice of teaching strategies used in the eighth grade mathematics classroom. This dissertation study reflects similar findings using the TIMSS-2007 data for the eighth grade science classroom. The current study and the Pong and Pallas study both used HLM techniques to analyze data, but the difference between the two was that the studies analyzed different subject areas in relation to class size. The current study used United States eighth grade science student data from the TIMSS-2007 while the Pong and Pallas study used United States eighth grade mathematics student data from the TIMSS-1995.

The predictor variables used in the two studies did have some overlap as well as some differences. The Pong and Pallas study included the following variables at the student level of the model: (a) number of books in the home, (b) parents education level, (c) two parents in the home, and (d) student gender. The study included the following variables at the classroom level: (a) number of topics taught, (b) frequency of students performing individual work, (c) frequency of students performing in small groups, (d) frequency of students performing in whole class teaching, and (e) frequency of students performing in class discussion, and (f) class size. At the school level the Pong and Pallas study includes the following predictor variables: (a) school enrollment, (b) type of community, (c) percentage of impoverished students, (d) percentage of low achieving students, and (e) average class size.

The current study used HLM to analyze relationships between student achievement and predictor variables at the school, classroom (teacher) and student level. At the school level, the predictor variables consisted of percent of affluent and disadvantaged students in the school as reported by the principal. At the classroom level the predictor variables used in the HLM study consisted of: (a) class size, (b) teacher age, (c) teacher gender, (d) teacher experience, (e) teacher education level, (f) is the teacher certified, and (g) frequency of constructivist teaching? The student level predictor variables consisted of student characteristics outside the classroom, which were: (a) student gender, (b) frequency of English spoken in the home, (c) number of books in the home, (d) was there a calculator in the home, (e) was there a computer in the home, (f) was there a desk in the home, (g) was there a dictionary in the home, (h) was there internet in the home, and (i) what is the education level of the parents? An interaction effect between frequency of constructivist teaching and class size was introduced to analyze the association between these variables.

The implication for these findings suggest that school districts that want to have teachers use constructivist teaching methods in the classroom cannot rely on decreasing the class size to allow the frequency of the constructivist teaching strategy to increase. The decrease in class size did not show an association with teachers increasing the use of constructivist methods in the class.

Research question 2 association between class size and student achievement. Another finding of this study was that the number of students in a classroom had no relationship with the student achievement on the science portion of the TIMSS-2007. Even if the analysis had been statistically significant the effect would have been of negligible importance. This was a remarkable relationship since it has been assumed by many educators and policymakers across the United States that the number of students in a class has a strong inverse relationship with student achievement.

Results of this study confirm the findings reported in previous TIMSS research studies indicating that class size was not significant when related to student achievement on the TIMSS. The Pong and Pallas (2001) study reported that class size did not have a significant association with mathematics achievement of United States eighth grade students on the TIMSS-1995. The current dissertation study reports the same findings for science achievement on the eighth grade TIMSS-2007. This finding was unexpected since it was considered common knowledge among educators in the United States that lower class size was related to higher student achievement. These surprising results could have implications for how school districts organize the classroom structure and how many students are placed within a classroom.

The current study and the Pong and Pallas study both used HLM techniques to analyze data, but the difference between the two was that the studies analyzed different subject areas in relation to class size. The current study used United States eighth grade science student data from the TIMSS-2007 while the Pong and Pallas study used United States eighth grade mathematics student data from the TIMSS-1995.

The predictor variables used in the two studies did have some overlap as well as some differences. The Pong and Pallas study included the following variables at the school level of the model: (a) number of books in the home, (b) parents education level, (c) two parents in the home, and (d) student gender. The study included only the class size variable at the classroom level. At the school level, the Pong and Pallas study included the following predictor variables: (a) school enrollment, (b) type of community, (c) percentage of impoverished students, (d) percentage of low achieving students, and (e) average class size.

The current study used HLM to analyze relationships between student achievement and predictor variables at the school, classroom (teacher) and student level. At the school level the predictor variables consisted of the percent of affluent and disadvantaged students in the school as reported by the principal. At the classroom level the predictor variables used in the HLM study consisted of: (a) class size, (b) teacher age, (c) teacher gender, (d) teacher experience, (e) teacher education level, and (f) is the teacher certified? The student level predictor variables consisted of student characteristics outside the classroom, which were: (a) student gender, (b) frequency of English spoken in the home, (c) number of books in the home, (d) was there a calculator in the home, (e) was there a computer in the home, (f) was there a desk in the home, (g) was there a dictionary in the home, (h) was there internet in the home, and (i) what is the education level of the parents? The coefficient for each predictor variable was then reported and the strength of associations between these variables and student achievement was determined.

The third area for comparison between the two studies was the effect size of class size in relation to student achievement as reported by the studies. The Pong and Pallas study did not report an effect size or standard error for the predictor variable class size. The current study had a 95% confidence interval of (-0.4, 0.4). Both studies did show that the association between class size and student achievement was not significant. The Pong and Pallas study showed a coefficient of -0.2 while the current study showed a coefficient of 0.0. If the association had been significant, the Pong and Pallas study reported an increase of one student in the class corresponds to a decrease of 0.2 points on the TIMSS score, which was essentially the same as reporting a decrease of 0.0 points.

These results can be helpful to school districts that are looking to cut costs because of the difficult economic situation the United States is currently experiencing. Increasing the number of students in a class may be a preferred cost cutting measure for a school district that wants to keep student achievement a priority. The implications of the findings from this study would allow school districts to save money by increasing the number of students in their secondary classes without worry of decreasing the student's achievement in eighth grade science. To further support this implication, the Secretary of Education Arne Duncan made remarks in a November 17, 2010 speech at the American Enterprise Institute, where he proposed increasing class size to help school districts solve budget issues. He stated that the increase of class size in appropriate situations at the secondary school level is a viable researched-based option to cut costs and not decrease student achievement. In this speech he also mentioned the importance of the Race to the Top program and how this program is being put in place to discover the most effective teaching strategies and expand those strategies to help with student improvement (Duncan, 2010).

The Race to the Top program emphasizes the need for educators to analyze data to find relationships between student achievement and school and classroom characteristics. The premise of the program was to provide educators with data to help them decide on what practices help students achieve at a higher level (*Race to the Top Executive Summary*, 2009). If educators use HLM to analyze the student and school data, they would most likely find that class size is not associated with student achievement.

The NCLB Act of 2001 did have recommendations of lowering class size especially at the early grades. One requirement for a school to receive grant money from the NCLB Act was to hire more teachers to reduce the number of students in the class. The policy was written for all grade levels, but did mention the need for the class reduction to be specifically targeted at the lower grades (*No Child Left Behind Act of*

2001, 2002b). The implications of this study suggest that if a school district wants to follow the NCLB policy they could target the lower grades for class size reduction only, and not apply the policy to the secondary schools.

Research question 3 what are the associations analyzed above for an urban and suburban school district. It has been explained that the current study cannot determine if the school taking part in the TIMSS-2007 was in an urban or suburban setting. It is important to note that the school questionnaire asked the principal what the population of the surrounding community was, not if the school was in an urban or suburban setting. The questionnaire did not define what was meant by surrounding community and may not have been a good indicator of a community being urban or suburban. The principal may have defined community as the school district, which tends to be a small geographical area in the northeast while in the south it tends to be a very large geographical area. If a school was located within a large city, the principal may have reported the community as the school district population or as the actual city population. These issues with interpreting the definition of community should be kept in mind when analyzing the findings of this study.

Research question 3 was analyzed with the same HLM model used for research questions 1 and 2 except community size was now added as a predictor variable. The results of the data analysis did not show a change in statistical significance for any of the predictor variables. The findings and implications stated previously did not change with the addition of the predictor variable community size.

The addition of the predictor variable community size had the result of community size being statistically significant and had an association with student achievement. The relationship suggested that a decrease of a school's community size was associated with an increase of student achievement. The size of the community reported by the principal was not well defined; therefore, it would be difficult to be confident of reporting an implication from this finding.

Limitations

Even though this dissertation used very reliable data from the science portion of the TIMSS-2007 it also included some limitations as well. One of the issues of limitation for this study was from the TIMSS data being observational and not being collected in a random fashion. The tested students were already in place within their classroom and were part of an observational study, which is not as powerful as a randomized experiment. For this reason, we cannot attach a causal relationship between the predictor and control variables with the dependent variable.

Another issue with analysis of the data was the limitation of the amount of information provided by the TIMSS student and teacher questionnaires. There may have been other pieces of information which were not included in the survey that have a significant impact on the dependent variable of student achievement. For example, when a student was asked how many books were in the household, we do not know how many of those books the student had read. The assumption was that if an average student has many books in their house they are more likely to read, but this was not asked directly of the student.

Even though these limitations exist, the relationships that have been found between the dependent variable and predictor variables as well as with the control variables can be thought of as being accurate. This information can be used by educational policymakers to justify actions to effectively and efficiently improve student achievement. For example, policymakers looking at this data may decide it is more important to have a certified teacher in the classroom than making sure the class sizes are smaller. These types of shift in priorities may help to improve student achievement in their school districts.

Recommendations

The findings of this study have shown that constructivist teaching methods were not associated with eighth grade science student achievement. The question of why are constructivist teaching methods so popular at this time and are these methods associated with other factors comes to mind after analyzing the TIMSS data. Constructivist teaching has been tied to improving students' problem solving abilities and critical thinking skills by educators who feel as though constructivism is the missing link to improving students' abilities in science. Researching the relationship between student achievement on specific types of questions that assess problem solving abilities and critical thinking skills with constructivist teaching methods can be a next step in analyzing the usefulness of this teaching strategy.

It would also be of interest to educators to have continuous studies on which predictor variables within the classroom and school levels have a significant relationship with improved student achievement. Specific examples of studies that may be of interest to teachers could be the relationship between eighth grade science student achievement on the TIMSS-2007 and: (a) the other teaching strategies available within the TIMSS data and, (b) the amount of homework given to students each night. Policymakers may be interested at reviewing the relationships between eighth grade science student achievement on the TIMSS-2007 and: (a) the length of the school day and, (b) the length of the school year.

The other factor that may be of importance to investigate is how all of these relationships change between rural, suburban and urban school districts. The TIMSS questionnaire did not ask this question of the school principal. It would be of interest to policymakers if the TIMSS were to ask the principal if the school was considered to be part of a rural, suburban, small city, medium city or large city school district. This additional piece of data would allow for these very different types of schools to not be combined together when policymakers decide on what actions would be best for school districts.

These additional findings may allow educators to refine their methods of educating students by providing the most effective strategies within the classroom.

Conclusion

Presently, science teachers are being informed by national educational organizations that constructivist teaching approaches used in the classroom allow for a student to have a deeper understanding of science concepts being taught. This presentation of constructivist teaching strategies as being a best teaching practice is not being questioned by mainstream educators and is considered to be the goal of all good science teachers. The constructivist strategy has been elevated to the status of being the most desirable teaching approach in a science classroom by most of today's educators. The discussion among teachers that is occurring is not if this is the correct approach but how this approach can be best implemented and introduced in the classroom. The current study calls into question the idea of constructivist teaching being related to a student improving their understanding of science concepts. If a teacher were to believe that frequency of constructivist teaching strategies were not associated with the science achievement of the students, they may be more likely to choose approaches that they feel are more appropriate for the situation in the class instead of trying to force constructivist teaching into as many of their lessons as possible.

The principals in the United States tend to be the instructional leaders of the school they are in charge of. They set the tone for what teaching strategies are acceptable and encouraged in the school. The principal tends to support the various teaching strategies they feel are effective and will allow for the highest student achievement. Since research in the classroom is uncommon at this time in the United States, the principals receive their information on teaching strategies from the national educational organizations, and rely on their expertise to properly inform the educational community. One of the organizations that promotes constructivist teaching methods is the National Science Teachers Association (NSTA). In a recent position statement on leadership in science education, NSTA explicitly stated that educational leaders must encourage the use of constructivist teaching approaches in the science classroom. This statement was simply put out there and was not attached to any referenced research (*Leadership in Science Education*, n.d.). If the principal was told by these organizations that constructivist teaching strategies, are the most successful, the principal then has an obligation to provide professional development to the teachers that encourages constructivist teaching strategies which in turn persuades teachers to use these strategies. If the principals were to use the research from the current study, they would most likely move away from the practice of telling the teachers what strategies are most effective and would provide free reign for the teacher to decide on the best teaching strategy for the situation at hand.

The national educational programs NCLB and Race to the Top have language that encourages teachers to use student data when deciding on what teaching methods are associated with improvement of student achievement. The one issue that may occur is that most educators do not know how to properly analyze data that has a multi-level nested structure. If HLM was not used and multiple regression techniques are used instead, educators will most likely calculate results that will have an increase in the probability of a Type 1 error.

School districts are not only worried about student achievement, but they are obligated to provide a high quality education at a reasonable cost. To keep the costs under control, a school district has to keep close tabs on the cost of the employees, which is the largest expenditure for a school district. If the number of employees can be decreased, a significant cost-savings may be possible. This study has shown that no relationship exists between class size and student achievement. School districts may be able to decrease their staffing costs by increasing their class sizes, while having students achieve at the same level as they would in a smaller class size.

If a school district has decided that constructivist teaching strategies are the preferred method of teaching, the district should not rely on making class size the factor that will allow for teachers to start using this teaching strategy. The implication of these findings was that teachers do not change their teaching strategy when the class size changes. The teacher may have a certain approach they are comfortable with and could be hesitant to change their strategy with a change in class size. If they have not tried the strategy before, they may feel as though going with a strategy they are used to will give the students a better chance of learning at a high level no matter the class size.

These findings may be of use to educators and school districts when decisions are made to maximize student achievement at the lowest cost. Additional findings can be made by educators and policymakers to help improve the educational system within the United States by using the TIMSS data to analyze what characteristics of the student, classroom and school have a positive relationship with student achievement.

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Appendix A

Correlation Matrix of Teaching Strategies from TIMSS-2007

Frequency of Teaching Strategy	2	3	4	5	6	7	8	9	10
1. Students Observe Natural Phenomenon	.306**	.308**	.367**	.303**	.056**	.010	.207**	.196**	.237**
2. Students Watch Teacher Demonstration	-	.244**	.188**	.209**	.163**	.262**	.244**	.199**	.248**
3. Students Design or Plan an Experiment		-	.571**	.487**	-.002	.066**	.297**	.173**	.208**
4. Students Conduct an Experiment			-	.694**	.027*	-.001	.214**	.144**	.241**
5. Students Work in Small Groups				-	.002	-.019	.227**	.203**	.273**
6. Students Read Textbooks					-	.391**	.197**	.231**	.089**
7. Students Memorize Facts						-	.269**	.241**	.051**
8. Students Use Scientific Formula							-	.336**	.248**
9. Students Give Explanation								-	.444*
10.Students Relate Topic to Daily Life									-

Note: * p-value < 0.05, ** p-value < 0.01.

Appendix B

In the literature review section of this study data tables presented were adapted from data tables used to present analysis of TIMSS data. Permission was given to adapt these data tables from articles written by the following authors: (a) J. Daniel House, (b) Suet-Ling Pong, and (c) Aaron M. Pallas.