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# Relationship Between Teacher Preparedness and Inquiry-Based Instructional Practices to Students' Science Achievement: Evidence from TIMSS 2007

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RELATIONSHIP BETWEEN TEACHER PREPAREDNESS AND INQUIRY-BASED  
INSTRUCTIONAL PRACTICES TO STUDENTS' SCIENCE ACHIEVEMENT:  
EVIDENCE FROM TIMSS 2007

A Dissertation

Submitted to the School of Graduate Studies and Research

in Partial Fulfillment of the

Requirements for the Degree

Doctor of Education

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August 2010

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Title: Relationship Between Teacher Preparedness and Inquiry-Based Instructional Practices to Students' Science Achievement: Evidence from TIMSS 2007

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The purpose of this study was to examine the relationship between teachers' self-reported preparedness for teaching science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated by TIMSS 2007. Six hundred eighty-seven eighth grade science teachers in the United States representing 7,377 students responded to the TIMSS 2007 questionnaire about their instructional preparedness and their instructional practices.

Quantitative data were reported. Through correlation analysis, the researcher found statistically significant positive relationships emerge between eighth grade science teachers' main area of study and their self-reported beliefs about their preparedness to teach that same content area. Another correlation analysis found a statistically

significant negative relationship existed between teachers' self-reported use of inquiry-based instruction and preparedness to teach chemistry, physics and earth science. Another correlation analysis discovered a statistically significant positive relationship existed between physics preparedness and student science achievement. Finally, a correlation analysis found a statistically significant positive relationship existed between science teachers' self-reported implementation of inquiry-based instructional practices and student achievement.

The data findings support the conclusion that teachers who have feelings of preparedness to teach science content and implement more inquiry-based instruction and less didactic instruction produce high achieving science students. As science teachers obtain the appropriate knowledge in science content and pedagogy, science teachers will feel prepared and will implement inquiry-based instruction in science classrooms.

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## CHAPTER I

### THE PROBLEM

In our 21<sup>st</sup> century world, understanding science is imperative in order for citizens to make informed decisions about themselves and the world in which they live. The rate of new discoveries and the development of increasingly sophisticated tools to study our world make science a very rapidly changing subject. Since the 1930s, the teaching of science has undergone many changes because of political, economical, social, energy, technological, and environmental concerns. New goals for science teaching are continuously being developed to help produce scientifically literate citizens.

Currently, American students lag behind international standards and continue underperforming in science (Martin, Mullis, Gonzalez, & Chrostowski, 2004; Parker and Gerber, 2000; Roth, Druker, Garnier, Lemmens, Chen, Kawanaka, Rasmussen, Trubacova, Warvi, Okamoto, Gonzales, Stigler, & Gallimore, 2006; Stigler & Hiebert, 1999). American schools are in need of improvement and science education has become a significant priority in our nation (Stigler & Hiebert, 1999). Because of the intense demands for highly qualified individuals in the field of science, the national

government continues to increase efforts to help the students in the United States perform better in science.

Science educators are working to improve science education. Given that science is a dynamic process and not just a body of knowledge, leading science organizations, such as the American Association for Advancement of Science (AAAS) and the National Research Council (NRC), stress the inclusion of inquiry-based science instruction into school science programs and curriculum. Inquiry-based instruction helps students achieve science understanding by combining scientific knowledge with reasoning and thinking skills (National Research Council, 2000). Inquiry-based teaching represents a departure from didactic or traditional methods of teaching science in which science is merely a body of facts to be memorized (Dewey, 1910a, 1910b, 1959; NRC, 1996b; Schwab, 1958, 1960, 1962, 1966;).

Inquiry-based teaching has a persistent history as the central method of good science pedagogy. A continuous body of evidence correlates inquiry-based science instruction with an increase in achievement (Escalada & Zollman, 1997; Freedman, 1997; Johnson, Kahle, & Fargo, 2006; Kahle, Meece, & Scantlebury, 2000; Mattern & Schau, 2002; McReary, Golde, & Koeske 2006; Morrell & Lederman, 1998; Okebukola, 1987; Oliver-Hoyo & Allen 2005; Parker & Gerber, 2000).

Therefore, it is important that science educators give priority to the implementation of inquiry-based learning opportunities. However, there are concerns regarding the implementation of inquiry-based instruction into the classroom. The use of inquiry-based instruction in classroom practice may not be commensurate with the emphasis of inquiry in science education literature (Aoki, Foster, & Ramsey, 2005).

#### Problem Statement

Since the 1950s, science educators and researchers have strongly advocated the perspectives of inquiry-based teaching in science classrooms (Allan & Powell, 2007; Oliver-Hoyo, Allen & Anderson, 2004; Unal & Akpınar, 2006). Increased attention has focused on helping science teachers to depart from traditional, didactic methods of instruction and provide opportunities for students to become engaged in more active, meaningful, and higher-level learning. Despite the evidence correlating inquiry-based science instruction with increased achievement, many teachers are still resistant to such changes in pedagogy. Studies of teaching and learning in science classrooms reported that most teachers are still using traditional, didactic methods (Harms & Yager, 1980; Seymour, 2002; Unal & Akpınar, 2006). Additionally, American students continue underperforming in

science (Martin et al, 2004; Parker and Gerber, 2000; Roth et al., 2006; Stigler & Hiebert, 1999). The problem of this study is to show teachers have limited preparedness with science content and pedagogy to teach science content through inquiry-based instructional practices.

#### Purpose of the Study

The purpose of this study will be to examine the relationship between teachers' preparedness to teach science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated on the TIMSS 2007 exam. Specifically, this study will investigate the orientation of teacher preparedness to teach biology, chemistry, physics, and earth science and the implementation of inquiry-based instruction to eighth grade students. Additionally, the identification of teachers' preparedness in relation to the use of inquiry-based instructional practices in the science classroom will be explored. Finally, a correlation between the teachers' implementation of inquiry-based instructional practices in science to United States eighth grade students' achievement in science as demonstrated on the TIMSS 2007 will be conducted.

## Questions Researched

This quantitative study seeks to answer the following questions:

1. What is the orientation of science teachers, with respect to their preparedness to teach specific science content to eighth grade science students?
2. What is the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect to their self-reported instructional practices in teaching science to eighth grade science students?
3. What, if any, relationship exists between teachers' beliefs about preparedness to teach science content and their self-reported instructional practices in teaching science to eighth grade science students?
4. What, if any relationship exists between student achievement in science and:
  - a. Teachers' beliefs about preparedness to teach science content to eighth grade science students?
  - b. Teachers' self-reported instructional practices in teaching science to eighth grade science students?

## Definition of Terms

Didactic Instruction- Didactic instruction traditionally has been conceptualized as the transmission of facts to students, who are seen as passive receptors. This instruction typically uses lecture format and instructs the entire class as a unit. Knowledge is presented as fact where students' prior experiences are not seen as important. Moreover, instruction does not provide students with opportunities to experiment with different methods to solve problems, but primarily uses a drill and practice format with a foundation on textbooks (Smerdon, Burkam, and Lee, 1999).

Inquiry-based Instruction- Since the National Science Education Standards (NSES) is at the center of U.S. science education improvement, it is well to consider its definition of inquiry-based instruction for this study: Inquiry-based instruction engages students in making observations; posing questions; reviewing what is already known in regards to experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; communicating the results; identifying assumptions; using critical and logical thinking; and considering alternative explanations; processing information, communicating with groups, coaching

student actions, facilitating student thinking, modeling the learning process, and providing flexible use of materials. (National Research Council (NRC), 1996 p. 23)

Trends in International Mathematics and Science Study 2007 (TIMSS 2007)- TIMSS 2007 is the fourth in a cycle of internationally comparative assessments dedicated to improving teaching and learning in mathematics and science for students around the world. Administered every four years at the fourth and eighth grades, TIMSS provides data about trends in mathematics and science achievement over time. TIMSS was designed to investigate student learning of mathematics and science and the way in which educational systems, schools, teachers, and students influence the learning opportunities and experiences of individual students.

#### Significance of the Study

The current trend in science education is to adopt instructional practices that follow research on how students learn and achieve. Given the emphasis placed on inquiry-based instruction in the Standards (NRC, 1996), the inclusion of inquiry-based instruction is important to a successful reform in science education (McReary, Golde, & Koeske, 2006). However, there have been few large-scale studies based on this premise. Previous studies based on

this presumption have been qualitative in nature and therefore provided little empirical evidence. This study, being quantitative in nature, will address this need and provide an accounting of the pedagogy of practicing science teachers as reported by those teachers. This will contribute to the information concerning teacher practice.

This study on teacher practice with respect to inquiry-based science instruction is important for several reasons. First, this study extends the research on teacher practice; because studies have shown (NRC, 2003) that, there has not been a significant increase in the practice of inquiry-based instruction since the release of the NSES. Comparing the current instructional methods used in science classrooms and student achievement in science will lead to an understanding of where educators align themselves in relationship to science education reform and will provide increased knowledge of the direction in which science educators are headed. Second, factors that influence teachers' practice are complex. One factor that has emerged in working toward the improvement of inquiry-based instruction is understanding the influence of teacher preparedness on teacher instructional practices. It is possible that teachers' beliefs about their preparedness to teach science influence their teaching practices, how they

believe content should be taught and how they think students learn. Determining a correlation between teacher preparedness to teach science to eighth grade students with their instructional style will provide a direction for future professional development programs with a possible emphasis on content and instructional methods. Third, as important as teacher practice is, the main goal of instruction is to affect student learning to promote science literacy. When compared with an international cohort of students, students in the United States are typically not among the high performers (Martin et al, 2004; Parker and Gerber, 2000; Roth et al, 2006; Stigler & Hiebert, 1999). The National Science Standards (NRC, 1996b) call for a major shift in pedagogical approach to teaching science, prompting studies on student achievement. The 2005 National Assessment of Educational Progress (NAEP) results for science assessment showed no significant change in student achievement in grades four and eight and a decline in performance at grade twelve since 1996 (Grigg, Lauko, and Brockway, 2006). This study will provide information that will contribute to a body of knowledge for the improvement of instruction in science classrooms and provide quantitative data to validate the benefits of inquiry-based teaching on science achievement.

## Limitations of the Study

The secondary analysis of existing data sets, like TIMSS 2007, provides an important opportunity for researchers concerned with science education. Miller (1982) describes the term secondary analysis as previously collected data sets of individual interviews or test scores when the unit of analysis is the individual or comparable measures for other units of analysis. The TIMSS 2007 international assessment of student achievement comprises written tests in mathematics and science together with a set of questionnaires that gather information on the educational and social contexts for achievement. One of the important considerations in the design and implementation of TIMSS 2007 was to produce a full database that contained all of the available data collected from the participants and to make these data available to educational researchers. Such a database has been developed and made public in a timely manner. The TIMSS 2007 database is a wealth of data for educational researchers to perform secondary analysis and potentially provide decision makers with valuable indicators of good curriculum design and provide teachers and teacher educators with advice on effective teaching and learning methods.

Using a large database such as TIMSS 2007 has many advantages and disadvantages. Although the TIMSS 2007 study presents enormous bodies of data for analysis, this study is a secondary analysis, which poses some cautions. It is important to recognize that other investigators collected the TIMSS 2007 data. As with all secondary analysis studies, it is important never to assume that another investigator collected a data set correctly. In this study, the researcher examined the sample selection procedures, sample size, response rates, field procedures, and coding conventions of the TIMSS 2007 carefully to ensure no deficiencies. The larger, national, professionally collected data sets that are available for secondary analysis are of higher quality than the smaller and local samples that most individual science education scholars can afford to collect (Hyman, 1972).

As is true for all secondary analysis, this study was limited by the data collected and definitions used in the TIMSS 2007 study. The data from the teachers were limited by the questions asked, the directions for those questions, and the response selections provided. Teachers were asked to recall past science classes taught to answer the questions used in this study. Discrepancies in the teachers' memory of a class could have influenced the

study. Any misinterpretations by teachers may have influenced the results of this study. Although TIMSS 2007 provides a wealth of educational data, there was only one method for examining teacher preparedness and instructional practices based on teacher responses to a questionnaire. Questionnaires are simple to administer and easily transfer into data files for statistical analysis.

#### Summary

Today's society is changing at rapid rates and science education programs need to prepare students for the world in which they live. Although the teaching of science has undergone much reform and recommendations for new goals for teaching science are developing continuously, the United States still lags behind their international counterparts. Improving science performance for all students is an important policy issue and educational concern.

Although the nature of inquiry-based instruction varies among science educators, its value is undeniable in current science education research. Given its importance, addressing inquiry-based instruction is essential in regards to influencing teachers' preparedness for inquiry-based instruction. The level of preparedness that teachers have for science and science instruction play a critical role in shaping their patterns of instructional

behavior (Plourde, 2002). The level of preparedness and confidence a teacher acquires may lead to providing effective inquiry-based instruction that in effect correlates to an increase in student achievement.

Chapter 1 describes the purpose of the study, providing a rationale for the guiding questions that provide focus and direction for the inquiry. Chapter 2 contains a review of relevant discourses including a description of the current state of science education in the United States, an historical overview of the changing goals of science education, with emphasis on the role of inquiry-based instruction, a discussion of the diverse definitions and description of inquiry-based instruction, a discussion of inquiry-based instruction within the constructivist-learning model, a discussion about the influence of teacher preparedness on teaching style, and an explanation of the TIMSS 2007. Chapter 3 explains the research methodology used in this study. Specifically, information is provided regarding secondary analysis methods research design, the sampling frame, and data collection procedures. It addresses the research methodology that frames this investigation and guides the research procedures. Chapter 4 presents the data analysis procedures and results. It includes a description of the

sample, the quantitative data results and descriptive statistics. Chapter 5 presents conclusions drawn from the data and discussions regarding the conclusions. Finally, implications for secondary science teachers and future research are discussed, followed by a summary of the study.

## CHAPTER II

### LITERATURE REVIEW

#### Introduction

The focus of this study was to examine the relationship between teachers' preparedness to teach science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated by the 2007 Trends in International Mathematics and Science Study (TIMSS 2007). This chapter provided the historical, theoretical, and research background for this study by reviewing the literature related to the indicators of inquiry-based instruction and the importance of this pedagogy for necessary student achievement in science.

The review of the literature is presented in six sections. An historical overview of the changing goals of science education, with emphasis on the role of inquiry-based instruction is presented in the first section. Diverse definitions and descriptions of inquiry-based instruction are described in the second section. Inquiry-based instruction within the constructivist-learning model is discussed in the third section. The influence of teacher preparedness on teaching style is discussed in the fourth section. The current state of science education in

the United States is presented in the fifth section. The 2007 Trends in International Mathematics and Science Study (TIMSS 2007) is explained in the sixth section.

History of Inquiry: From Dewey to Standards

*Inquiry and the National Science Education Standards* (National Research Council (NRC), 2000) stated that inquiry teaching and learning in school programs is less than a century old. As early as 1909, John Dewey stressed there was too much emphasis on facts without enough emphasis on science for thinking and an attitude of mind. Dewey (1910) proclaimed that children should experience science and not be passive recipients of ready-made knowledge. He contended "knowledge is not information, but a mode of intelligent practice and habitual disposition of mind" (p.125). Dewey (1910) articulated the objectives of inquiry-based instruction: developing thinking, formulating habits of mind, learning science subjects, and understanding the process of science.

In Dewey's model, the student is actively involved, and the teacher has a role as a facilitator and guide for the student. Dewey expanded his views and encouraged that science educators teach their students so that they could add to their personal knowledge of science. To accomplish this, teachers need to require students to address problems

that they want to investigate and apply it to the observable phenomena (Dewey, 1916). According to Dewey (1938), concepts and problems to be studied must be related to students' experiences and within their intellectual capacity; therefore, the students are to be active learners in their searching for answers. The wisdom and philosophy of Dewey (1938) suggests that providing students with a supportive environment and the freedom to construct their own knowledge motivates them to become engaged learners. Dewey's model was the basis for the Commission on Secondary School Curriculum (1937) entitled *Science in Secondary Education* (Barrow, 2006).

The launching of Sputnik I in 1957 caused the United States to question the quality of the science teachers, the science curriculum, and the methods for science instruction used in schools. The traditional science courses were not preparing young people for understanding either the world in which they were living or the future (Collette & Chiappetta, 1994). Science teaching, then, was portrayed as dull, inadequate, and not meeting the demands of the times (Barrow, 2006). The circumstances called for reform in science education. The National Science Foundation (NSF) had funded the development of innovative science curricula with special attention to improving science

processes as individual skills such as observing, classifying, inferring, and controlling variables (Barrow, 2006). The launching of Sputnik sparked the most innovative and spectacular changes in the philosophy of science education ever seen in American schools (Collette & Chiappetta, 1994).

Joseph Schwab provided the foundation for inquiry as a relevant theme in science curriculum reform in the 1950s and 1960s (1958, 1960, 1962, & 1966). Schwab, (1962), in "The Teaching of Science as Enquiry," supported Dewey's sentiments on the importance of inquiry-based instruction in school settings. According to Schwab, scientists no longer conceived science as stable truths to be verified; rather they viewed it as principles for inquiry, conceptual structures revisable in response to new evidence (Bybee, 2000). Schwab (1960) described two types of inquiry: Stable and fluid. Stable inquiry uses current principles to add to the scientific knowledge base, which is a growing body of knowledge. Fluid inquiry requires the use of invention to question current principles that may lead to scientific revolutions. Schwab (1966) believed that students should be given the opportunity to view science as a series of conceptual structures that should continually

be revised when new information or evidence is discovered.

Schwab stated,

In the very near future a substantial segment of our public will become cognizant of science as a product of fluid enquiry, understand that it is a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by. (p.5)

Inquiry-based practices have been heralded as essential to students' development of what Dewey (1910) calls "habits of minds," a way of thinking that promotes scientific reasoning skills. Consistent with Dewey's thoughts, Schwab encouraged science to be taught in a way that was parallel with the way modern science operates. Schwab (1966) emphasized the importance of getting students actively involved in the learning process through means of investigation and not just the content fact of science. He also encouraged science teachers to use the laboratory to assist students in their study of science concepts. This facet is found in the *Biology Teachers' Handbook* (Biological Sciences Curriculum Study, 1978) in which Schwab called for the use of "Invitations to Enquiry."

Using this strategy, teachers utilize sixteen activities providing students with research readings that come from articles, reports, or books. The teacher and students are then encouraged to engage in dialogue regarding the problems, data, analyses, and conclusions derived by the investigators. Hence, Schwab advocated that students should read about alternative viewpoints and explanations of scientific inquiry. He recommended inquiry-based instruction as the preferred format for teaching science concepts so students could be active in the learning process.

In 1964, F. James Rutherford explained that even though science teachers opposed didactic methods of instruction and supported inquiry-based instruction, in reality, the teaching of science does not model science as inquiry. Furthermore, Rutherford noted that it is not clear as to what teaching with inquiry means. Some science teachers see inquiry construed as part of the science content itself. Other science teachers envisioned inquiry as a particular teaching strategy for the teaching of scientific content.

Rutherford (1964, pp.80-84) developed three conclusions about inquiry-based instruction in science classrooms. First, it is possible to gain a sensible

understanding of science as inquiry, once teachers recognize the necessity of considering inquiry as content and operate on the premise that the concepts of science are properly understood only in the context of how they were arrived at and of what further inquiry they initiated. Second, it is possible to learn something of science as inquiry without having the learning process follow an exact set of the methods of inquiry used in science. Third, the laboratory can be used to provide the student experience with some components of the investigative techniques used in science. Rutherford stated that until science teachers understand "a rather thorough grounding in the history and philosophy of the sciences they teach, this kind of understanding will elude them, in which event not much progress toward the teaching of science as inquiry can be expected" (1964, p.84).

During the 1970s and 1980s the National Science Foundation (NSF) supported a project that analyzed and synthesized a number of national surveys, assessments, and case studies about the status of science education in the United States (Harms & Kahl, 1980; Harms & Yager, 1981; Helgeson, Blosser, & Howe, 1997). Project Synthesis (Harms & Yager, 1981) was a compilation of three major NSF sponsored projects which included a review of 1955-1975

literature (Helgeson, Blosser, & Howe, 1997), case studies by Stake and Easley (1978), and the 1977 national survey of science, mathematics, and social studies education, which collected data on materials, practices and the leadership of science education(Weiss, 1978). In addition, other sources, such as the Office of Education funded project, the National Assessment of Educational Progress (NAEP), completed its third comprehensive assessment of science knowledge, skills, attitudes and educational experiences of precollege students, based on a broad set of objectives developed by NAEP. As a set, these four studies provided a more comprehensive picture of science education and became the backbone of the database from which Project Synthesis worked.

Using the data in developing a discrepancy model, there were four different goal clusters developed: personal needs, societal issues, academic preparation, and career education and awareness. The greatest emphasis was on academic preparation. Welch, Klopfer, Aikenhead, and Robinson (1981) contributed a significant portion of this review that was devoted to the role of inquiry-based science instruction. They concluded that science educators were using the term "inquiry" in a multitude of ways that encompasses inquiry as content and inquiry as an

instructional technique. Science educators were unclear about the term's meaning. It was reported that science teachers view inquiry positively, however; "little evidence exists that inquiry is being used" (Hurd, Bybee, Kahle, & Yager, 1980). In general, they found that although there was a positive attitude toward the importance of inquiry-based instruction, there is a discrepancy between about the importance of inquiry and the attention given it in practice. Science teachers identified the following reasons for not employing inquiry-based instruction: limited teacher preparation, including management; lack of time; limited available materials; lack of support; emphasis only on content; reading were too difficult, the students were immature; experiments were too risky; hard to track the progress of students; too expensive and difficult to teach (Welch et al., 1981; Constenson & Lawson, 1986).

Project 2061, the long-term efforts by the American Association for the Advancement of Science (AAAS) to reform K-12 science, identified what all students should know and be able to do when they graduate at the end of grade 12. The results of Project 2061 have been publications like *Science for All Americans* in 1989 and *Benchmarks for Science Literacy* in 1993. *Science for All Americans* (Rutherford & Ahlgren, 1989) has a broad view of defining

scientific literacy and made several recommendations for historical perspectives, habits of mind, and that teaching should be consistent with the nature of scientific inquiry. *Science for All Americans* is based on the belief that the science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. *Science for All Americans* (AAAS, 1990) claimed that by 2061 a generation of science literate citizens would be achieved. *Benchmarks for Science Literacy* (AAAS, 1993) organized the topics into K-2, 3-4, 5-8, 9-12 grade-level groupings and provided specific results of learning about the nature of science, gaining historical perspectives, and acquiring good habits of mind such as informed skepticism, curiosity, and openness to new ideas. Both of these works have made important statements about specific goals and benchmarks about inquiry-based science instruction.

The *National Science Education Standards (NSES)* (National Research Council, 1996b) publicized a new report about inquiry-based science instruction. In this report,

the NSES defined what all students in science classrooms should know and be able to do by grade twelve. In addition, the NSES described the kinds of learning experiences students need to achieve scientific literacy. This publication advocated the idea that inquiry-based instruction is pertinent for student achievement of scientific literacy.

The NSES addressed inquiry in two ways. First, there is inquiry as content in which the students should both understand scientific inquiry and the abilities they should develop from their experiences with scientific inquiry. Second, inquiry is associated with teaching techniques and the processes of learning with inquiry-oriented activities. To provide clarification, the NRC (2000) published *Inquiry and the National Science Education Standards* and identified five essential features of inquiry (p. 25), regardless of the grade level:

1. scientifically oriented questions that engage the students;
2. evidence collected by students that allows them to develop and evaluate their explanations to the scientifically oriented questions.

3. explanations developed by students from their evidence to address the scientifically oriented questions;
4. evaluation of their explanations, which can include alternative explanations that reflect scientific understanding; and
5. communication and justification of their proposed explanations.

The NRC (2000) asserted these essential features introduce students to many important aspects of science, while helping them develop a better knowledge of science concepts and processes. In addition, teachers of science must know that inquiry involves (a) the cognitive abilities that their students must develop; (b) an understanding of methods used by scientists to search for answers for their research questions; and (c) a variety of teaching strategies that help students to learn about scientific inquiry, develop their abilities of inquiry, and understand science concepts (Bybee, 2000; NRC, 1996b, 2000). The NRC (1996b) included a list of increased emphasis and decreased emphasis regarding inquiry (see Figure 1). These statements allow teachers of science to determine whether their perspectives about the three domains of inquiry are compatible with the reform movement in science education.

Changing Emphases to Promote Inquiry	
Less Emphasis on	More Emphasis on
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

*Figure 1.* The National Science Standards envision change throughout the system. The teaching standards encompass the above changes in emphasis (National Research Council, 1996b. p. 113).

In addition, the NRC (1996b, 2000) acknowledges that not all science concepts can or should be taught using inquiry-based instruction. The following three paragraphs summarize interpretations about inquiry from the NRC in

1996, and each of these domains was clarified by the NRC in 2000.

The fundamental abilities of inquiry specified by the NRC (2000, p. 19) are to:

1. identify questions that can be answered through scientific investigations (students formulate a testable hypothesis and an appropriate design to be used).
2. design and conduct scientific investigations (using major concepts, proper equipment, safety precautions, use of technologies, etc., where students must use evidence, apply logic, and construct an argument for their proposed explanations).
3. use appropriate tools and techniques to gather, analyze, and interpret data.
4. develop descriptions, explanations, predictions, and models using evidence where the students' inquiry should result in an explanation or a model.
5. think critically and logically to make the relationships between evidence and explanations
6. recognize and analyze alternative explanations and predictions.
7. communicate scientific procedures and explanations.
8. use mathematics in all aspects of scientific inquiry

Accomplishing these eight skills requires science teachers to provide many inquiry-based investigation opportunities for students (Barrow, 2006). According to the NRC (2000), when students practice inquiry, it helps them develop critical thinking abilities and scientific reasoning, while developing a deeper understanding of science concepts.

The second domain of inquiry instruction is the development of understanding about how scientists work in the field of science. This domain of inquiry concentrates on the reasoning for which scientific knowledge changes when new evidence, methods, or explanations occur among members of the scientific community. Therefore, they will be very similar for each grade-level, except with increasing complexity (NRC, 2000). The categories identified by the NRC (2000, p. 20) are as follows:

1. conceptual principles and knowledge that guide scientific inquiries;
2. investigations undertaken for a wide variety of reasons—to discover new aspects, explain new phenomena, test conclusions of previous investigations, or test predictions of theories;

3. use of technology to enhance the gathering and analysis of data to result in greater accuracy and precision of the data;
4. use of mathematics and its tools and models for improving the questions, gathering data, constructing explanations, and communicating results;
5. scientific explanations that follow accepted criteria of logically consistent explanation, follow rules of evidence, are open to question and modification, and are based upon historical and current science knowledge; and
6. different types of investigations and results involving public communication within the science community. (To defend their results, scientists use logical arguments that identify connections between phenomena, previous investigations, and historical scientific knowledge; these reports must include clearly described procedures so other scientists can replicate or lead to future research).

The third domain of inquiry from the NSES is in the teaching standards (NRC, 2000). Several inquiry-based teaching strategies facilitate students' developing a

better understanding of science. Science teacher educators need to provide experiences and information so that future teachers of science can provide high quality inquiry-based science lessons.

Science method courses may need to provide future science teachers with exemplary examples of inquiry-based instruction as a content area. Aspects of inquiry-based teaching include strategies to assess students' prior knowledge and ways to utilize this information in their teaching; effective questioning strategies, including open-ended questions and long-term investigations, rather than single-period verification-type investigations (Barrow, 2006). The vast majority of their K-12 and college science laboratory experiences have not modeled inquiry as content. Teachers need to have inquiry modeled for them because they need to see the benefit for their future students. For most future science teachers, this may not have been their personal experience. Providing a model of quality instruction could enhance their view of scientific literacy (Barrow, 2006).

Over the past century, inquiry-based instruction has been prevalent in research literature. Science educators, researchers, and philosophers have provided multiple interpretations of inquiry. Consequently, teachers of

science are left to interpret the foundation, implementation, and results of inquiry-based instruction and the affects on student learning. To help clarify, the NRC (2000) released *Inquiry and the National Science Education Standards*, however research support the notion that science educators are still unclear about what inquiry means coupled with the uncertainty of implementing inquiry-based instruction. Inquiry-based instruction has been an established concept for over a century in science education. Although many scholars (Barrow, Dewey, and Schwab) and the NRC, have discussed guidelines for implementation over a century, the concept is still widely discussed in the realm of science educators. Claims that inquiry-based instruction is a necessity for student success in a highly competitive, twenty-first century, technological world are still prevalent in science education.

#### Defining Inquiry-Based Science

Inquiry-based science instruction emerged from science education reform (Buck, Latta, & Leslie-Pelecky, 2007; Haefner & Zembal-Saul, 2004; Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004). Inquiry-based science instruction is highly encouraged by the National Research Council (NRC) and the American Association for the

Advancement of Science (AAAS) in order to produce better science literate students. However, despite its major importance in the science education community, scholars conclude that the current definitions of inquiry-based instruction offer a vague description of the term and its classroom applications (Anderson, 2002; Colburn 2006; Cuevas, Lee, Hart, & Deaktor, 2005; Flick, 2000; Haefner & Zembal-Saul, 2004; Keys & Bryan, 2001; Martin-Hauser, 2002; Wee, Shepardson, Fast, & Harbor, 2007; Windschitl, 2003).

The National Science Education Standards (NSES) (National Research Council, 1996b) defines inquiry as follows:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p. 23)

Although the NSES included the definition and examples of inquiry-based teaching of science, these broad definitions do not provide adequate direction for teachers practicing inquiry-based instruction in their classrooms (Anderson,

2002; Flick, 2000; Keys & Bryan, 2001; Keys & Kennedy, 1999). Songer et al. (2003) stated:

Science educators and researchers often hold a narrow, somewhat idealistic representation of scientific inquiry as "the kind of thinking scientists engage in" or other poorly defined constructs, in part, because few other models, and few well-defined models, of inquiry science exist. Consistent with the representation, inquiry guides can often present a monolithic view of what inquiry should look like in classrooms. (pp.511-512)

This poses a critical challenge for teachers implementing inquiry-based instruction. Teachers develop and enact their own ideas of inquiry-based instruction in their classroom practice. These conceptions may not necessarily match with the vision of the reform documents or be commensurate with the emphasis of inquiry-based instruction in the science education literature (Aoki, Foster, & Ramsey, 2005; Windschitl, 2003). Windschitl (2004) explained that diverse ideas about inquiry-based instruction exist among not only science teachers, but also are "codified" in authoritative documents, reinforced by textbooks, and embodied in the practices of educators who

promote the use of inquiry-based instruction as well as those who favor methods that are more traditional.

Flick et al. (1997) argued that our knowledge about inquiry-based science teaching has developed from the perspective of student's behaviors and experiences in inquiry rather than teachers' generation and management of these meaningful inquiry experiences. Furthermore, if inquiry is to become a practicable, mainstream approach to science pedagogy, researchers and teachers must become more explicit about the behaviors and thoughts of educators engaged in inquiry-based teaching (Flick et al., 1997). Newman, Abell, Hubbard, McDonald, Otaala, and Martinini (2004) explained, "the definition of inquiry-based teaching in science is dynamic and context dependent" (p.273). Keys and Kennedy (1999) believed that any attempt for an operational definition of inquiry-based science teaching needs to come from grounded classroom practice, which would include teachers' views of the pedagogy. Keys and Bryan (2001) supported the idea that one true definition of inquiry-based instruction is non-existent and every educator is dependant upon constructing his/her own understanding of the concept. They expressed that "multiple modes and patterns of inquiry-based instruction are not only inevitable but also desirable because they

will paint a rich picture of meaningful learning in diverse situations" (p.632). However, this poses difficulty with providing a single definition of inquiry and its classroom applications is quite difficult (Henson, 1986).

In the research literature, several scholars tried to structure specific qualities and activities in identifying inquiry-base science teaching. Crawford (2000) presented some of the popular terms used by practicing teachers to refer inquiry-based instruction as doing science, hands-on science, and real-world science. Inquiry-based instruction extends from "traditional hands-on" to "student research" (Bonnstetter, 1998). Eick and Reed (2002) contended confirmatory type teaching activities that pursue predetermined procedures and have known outcomes should not be considered inquiry-based instruction. More radically, Hein (2002) contended that any teaching activities that do not allow for multiple results should not be considered inquiry-based instruction. His definition excluded most laboratory work in classrooms, because they are usually intending to demonstrate a concept and not a novel or diverse conclusion. National Research Council(1996b) described inquiry-based instruction as "the activities the students in which they develop knowledge and understanding

of scientific ideas, as well as an understanding of how scientists study the natural world" (p.23).

Kluger-Bell (1999) explained effective inquiry-based instruction involves students learning through direct interaction with materials and concepts. One necessary sign of inquiry-based instruction is the level of control that the students have in determining various aspects of the learning experience. Here inquiry-based instruction is determinant on the nature of the learning outcomes, the design of the investigation procedure, and the degree of student control on the learning experience. The NRC (1996b) elaborated the inquiry process as follows:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

This allows students to engage in various aspects of inquiry as they learn the scientific way of knowing the natural world.

According to the NRC (1996b), inquiry-based instruction embraces students with first hand events that incorporate observation, data collection, reflection, and analysis. Sutton and Krueger (2001) explained inquiry-based instruction may also include reading, discussion, and research where educators should use different strategies to develop the knowledge, understandings, and abilities for various content areas. They contend that inquiry-based instruction need not always be a hands-on experience. Hodson (1999) categorized inquiry-based instruction as either "literature/media based" or "field experience/laboratory-based" (p.246).

Settlage (2007) suggested that the commonly held framework of inquiry-based science instruction has remained essentially the same from the middle of the previous century until today: Inquiry begins with a question based on observation, which ultimately leads to a conclusion based on evidence. However, Keys and Bryan (2001) challenged the notion that there is a simple, preconceived framework of inquiry waiting for discovery by students. Based on a constructivist view of inquiry, Keys and Bryan

proposed that inquiry is individually constructed by each student is based on his or her interaction with the physical world and abstract ideas. Rather than a lock-step trip through the various components of the inquiry process, Keys and Bryan (2001) presume that students construct their own knowledge about science, about how scientists work, and about the inquiry process as they interact with their peers, their teacher, and the classroom context.

Numerous definitions of inquiry-based instruction are found in the education literature. Flick (2003) provide a three-part definition that includes the process of how modern science is conducted, an approach for teaching science, and knowledge about the nature of science. Other definitions encompass processes, such as using investigative skills; actively seeking answers to questions about specific science concepts; and developing students' ability to engage, explore, consolidate, and assess information (Lederman; 2003). According to the NRC (2000), Inquiry-based instruction is student-centered or open when students generate a question and carry out an investigation. It is teacher guided when the teacher selects the question and both students and teacher decide how to design and carry out an investigation. It is teacher centered or explicit when the teacher selects the

questions and carries out an investigation through direct instruction or modeling (National Research Council, 2000). Furthermore, NRC (2000) presented essential features of inquiry-based classrooms:

- Learners are engaged by scientifically oriented questions
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations. (p.25)

Finding numerous definitions for inquiry-based science instruction in research literature is not a difficult task. However, each offer variance in the types of activities and learning opportunities for students. A critical challenge in the study of inquiry-based science instruction is the lack of a clear conception of what it involves (Cuevas, Lee, Hart, & Deaktor, 2005). This may result in science

educators developing and enacting their own conceptions of inquiry-based instruction with their students and these conceptions may not draw a parallel with the intention of inquiry-based instruction in the research literature.

#### Inquiry within a Constructivist-learning Model

The National Science Education Standards in the United States call for a reform of science education based on the use of inquiry grounded in the constructivist-learning model (Haney, Lumpe, Czerniak, & Egan, 2002; National Research Council [NRC], 1996). Learning through inquiry-based instruction mirrors scientific inquiry in that students research and gather information and data to answer questions in support of learning scientific principles. Inquiry-based instruction helped provide positive student gains in cognitive achievement, process skills, and attitude toward science (Anderson, 2002; Shymansky, Hedges, & Woodworth, 1990). The constructivist perspective provides a philosophical background for reforms and is a dominant paradigm in the field of science education.

Constructivism focuses on characterizing the cognitive growth of children, where learning is understood as a constructive process of conceptual growth, often involving reorganization of concepts in the learner's understanding and development in general cognitive abilities such as

problem-solving strategies and metacognitive processes (Straits & Wilke, 2007). Brooks and Brooks (1993) defined the following five principles as constructivist pedagogy. These include the following: posing problems of emerging relevance to learning, structuring learning around primary concepts, seeking and valuing students' points of view, adapting curriculum to address students' supposition, and assessing student learning. Constructivism provides a philosophical view of learning where learners actively construct their own knowledge because of their interactions with the natural world. The construction of knowledge takes place in a socio-cultural context, is mediated by their prior knowledge, and then is applied in new situations (Straits & Wilke, 2007). A teaching style like inquiry-based instruction that recognizes the constructivist learning model attracts much attention, because it suggests ways for student learning and the changes in teaching that are essential for it to occur.

Grounded in constructivist philosophy, inquiry-based instruction provides students with learning opportunities where the construction of understanding a new concept is based on student exploration of an authentic problem using the processes and tools of the discipline (Straits & Wilke, 2007). From the constructivist perspective, Inquiry-based

instruction impacts learning in six ways. First, it requires that the curriculum be customized to the student's prior knowledge. Second, it emphasizes problem solving in the form of hands-on activities. Third, the teacher becomes a facilitator by connecting facts and fostering new understanding in students. Fourth, the teachers individualize their teaching strategies to student questions and comments and encourage students to analyze, interpret, and predict data. Fifth, teachers rely on open-ended questions or activities and foster collaboration and dialogue among peers. Sixth, assessment becomes part of the learning process, where students play a role in evaluating their own progress. Concurring with the constructivist approach, inquiry-based instruction provides opportunities for students to redefine, reorganize, and elaborate their current concepts through interactions with objects, peers, and events in the environment (Bybee, 1993). In accord with constructivism, inquiry-based instruction emphasizes student development of knowledge through mental and physical active participation. Students are encouraged to make meaning; the students are usually involved in developing and modifying their knowledge schemes through experiences with phenomena and through expository talk and teacher intervention (Driver, 1989).

Many reformers advocate a move away from traditional, didactic, instruction where the students are passive receptors of knowledge, towards more student-centered, inquiry-based teaching that focuses on explorations and experimentation. Constructivist and inquiry-based learning is purported to produce meaningful learning, improves attitudes toward learning and science, increases knowledge acquisition and retention, promotes self-efficacy and motivation, fosters community among students, and promotes the view that science is a process and not merely a set of facts to memorize (Burrowes, 2003; Ebert-May, Brewer, & Allred, 1997; Straits & Wilke, 2003, 2007; Svinicki, 1998). In a meta-analysis of the 1990 NELS data, Von Secker (2002) reviewed demographic data of 4,377 students in 1,406 classes as well as surveys completed by their biology teachers. Von Secker identified five elements of constructivist teacher practices and examined their effects in biology classes. She also examined the effects of these elements on the achievement of the students. The purpose was to learn the significance of the effects. The five elements of constructivist practices included the degree of emphasis to which teachers increased student interest and engagement, use of appropriate laboratory techniques, problem-based learning, student initiation of further

supplemental research, and appropriate use of scientific writing methods. These elements were aligned with reforms designed to promote inquiry-based learning opportunities recommended in the National Science Education Standards (1996). Each of the five identified constructivist teacher practices contributed to a significant increase in overall achievement ranging from .22 to .36 standard deviations. These five identified constructivist practices resulted in increased student learning.

Aligned with constructivist philosophy, inquiry-based instruction provides learning opportunities through the construction of a new understanding based on student exploration of an authentic problem using the processes and tools of the discipline (Wilke & Straits, 2006). Inquiry-based teaching encourages students to make sense out of curriculum content where the students are usually involved in developing and modifying their knowledge schemes through experiences with phenomena and through expository talk and teacher intervention (Driver, 1989). The National Science Education Standards (NSES) (National Research Council, 1996b) and the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) both stress the need for inquiry-based learning. Inquiry allows students to experience science as it occurs in the

laboratory or in the natural environment, where scientists create new knowledge through constructivist processes.

#### Teacher Preparedness and Inquiry-Based Instruction

Inquiry-based instruction is a major trend in science education reform. At the heart of this reform is the notion that students need to be engaged in activities that develop understanding of the investigation processes. The National Science Education Standards (NSES) Teaching Standard B (National Research Council, 2000) encourages teachers to use the "skills of scientific inquiry, as well as the curiosity, openness to new ideas, and skepticism that characterizes science" (p. 32). When teachers display these values of everyday science, students will assimilate similar attitudes in their dispositions (National Research Council, 2000). However, to engage in this type of pedagogy, teachers need to be prepared with a knowledge base for how inquiry-based instruction is implemented successfully. Teachers not only need to believe that inquiry-based teaching is the best instructional approach to support their students' learning, but also, teachers need confidence in their content knowledge and their ability to teach using inquiry-based approaches (NRC, 1996b).

Factors that influence teachers' practice are complex and numerous. One factor that has emerged in research literature is the effect teacher preparedness has on teacher practice. Teacher preparedness is defined as a continuous process of self-renewal and professional development, where the teacher works to influence and improve the quality of one's own knowledge of content and pedagogy (Bolyard & Moyer-Packenham, 2008). Increasingly, teachers are being required to have a thorough grounding in the subjects they teach, so they can guide their students effectively through subject area content and respond knowledgeably to students' questions and in class discussions (Bolyard & Moyer-Packenham, 2008).

Teachers are the primary means of curriculum implementation. Regardless of how closely prescribed the curriculum, or how explicit the textbook, it is the actions of the teacher in the classroom that most affect student learning (Mayer, Mullens, & Moore, 2000). Mayer et al. (2000) suggested that to ensure high levels of academic achievement, teachers should have high academic skills, teaching in the field in which they received their training, have more than a few years of experience, and participate in high-quality induction and professional development programs. Effective teacher practice is

achieved by knowledgeable, committed teachers who tailor and adapt their practices to the ongoing needs of their students in order to accomplish high levels of achievement across heterogeneous groups of learners (Alton-Lee, 2003). The key to better learning for students is better teaching (Darling-Hammond, 2000). A teacher's level of preparedness in their content area of expertise is of critical importance (Darling-Hammond, 2000).

When discussing teacher preparedness, one factor to consider is the content knowledge a teacher acquires in their field of expertise. Research indicated links between teachers' subject matter preparation and teacher effectiveness (Darling-Hammond, 2000; Rice, 2003; Wilson & Floden, 2003). Monk (1994) showed the number of science courses taken by a science teacher had a positive influence on student achievement in science. The results of studies examining the relationship between teachers holding subject-specific degrees and student achievement are positive at the secondary level (Goldhaber & Brewer, 1997, 2000). In their study, they found science teachers holding a bachelor's degree in science, rather than having no degree or a bachelor's degree in another subject to have a statistically positive relationship with student achievement (Goldhaber & Brewer, 1997, 2000). Researchers

indicated that students having teachers who are fully certified in their content area scored significantly higher on achievement tests than students with out-of-field teachers (Hawk, Coble, & Swanson; 1995). Teacher content preparedness has been widely shown to have a large impact on student achievement (Saderholm & Tretter, 2008).

The importance of content knowledge emphasizes a potential area for improvement in middle school science teacher preparation (Saderholm & Tretter, 2008). A major focus in this study is the relationship of the preparedness of 8<sup>th</sup> grade science teachers on the achievement of 8<sup>th</sup> grade science students. Goldhaber and Brewer (1998) found many middle school science teachers do not have a bachelor's degree in the subject they are being asked to teach. Furthermore, most of the middle school teachers who possess a degree in science have a degree in life science, and only a minority of those have many hours in the earth and physical sciences (Chaney, 1995). This trend is problematic for middle school science teachers; because many middle school curriculums are integrated in nature, with several science content areas per grade level (Saderholm & Tretter, 2008).

Another factor to consider when discussing teacher preparedness is the pedagogical knowledge a teacher

acquires in their field of expertise. Studies of mathematics and science teachers' pedagogical knowledge have reported positive effects of education training on teachers' knowledge and practices (Adams & Krockover, 1997). At the secondary level, studies indicate that coursework taken in subject-specific pedagogy is positively related to implementing sound pedagogy and secondary students' achievement (Chaney, 1995; Monk, 1994). A major trend in science education reform is an emphasis for science teachers to use inquiry-based instruction. However, for teachers to engage in inquiry-based instruction successfully, teachers need to have the necessary training. Teachers need to be confident in their ability to teach using inquiry-based techniques.

The reasons that influence teachers' pedagogy are multifaceted. Content knowledge and pedagogical knowledge are two factors that contribute to the preparedness of teachers. Teachers need confidence and a feeling of preparedness in their content knowledge and in their ability to teach using inquiry-based approaches (NRC, 1996b).

#### The Current State of Science Education

In the twenty-first century world, science achievement is imperative in order for citizens to make informed

decisions about themselves and the world in which they live. There is a strong interest among educators, researchers, and policy-makers in understanding the determinants of science achievement in the United States. Recent international studies have shown that students in the United States lag behind their peers in other countries in science achievement (Martin, Mullis, Gonzalez, & Chrostowski, 2004; Parker & Gerber, 2000; Roth, Druker, Garnier, Lemmens, Chen, Kawanaka, Rasmussen, Trubacova, Warvi, Okamoto, Gonzales, Stigler, & Gallimore, 2006; Stigler & Hiebert, 1999). Science achievement in middle and high school is of critical importance because it prepares our students for future advancements in our competitive and technological society (Martin et al, 2004).

The teaching of science has undergone many changes over the past century, because of political, economical, social, energy, technological, and environmental concerns. New ideas and goals for science teaching are continuously being developed to help produce scientifically literate citizens. The content of most K-12 science curricula and delivery of the content in the United States are not appropriate for meeting the individual and social needs of people living in our twenty-first century world (American Association for the Advancement of Science (AAAS), 2001).

Furthermore, there is little uniformity in classrooms around the country (Pederson & Totten, 2001), resulting from an inconsistent educational framework in teaching a diverse group of students at every readiness level. In addition, many of today's science teachers are unprepared for classroom practice, design and implement poor lessons based on low standards (Eisenhart, Finkel, & Marion, 1996). Because of this variability and consequential curricular instability, many schools are failing to produce high school graduates who are adequately prepared for the workplace or college-level classes. Some college freshmen must enroll in remedial courses in order to be prepared for collegiate standards that require rigorous high school academic requirements (Arenson, 2004). Problems such as these diminish the nations' prospective capacity for being a global competitor in the economy and a leading voice in serious scientific, technological, and environmental concerns (Eisenhart et al., 1996).

International researchers are also producing evidence of inadequacies in American science education. Students in the United States do not exhibit the high levels of educational achievement in the sciences that their peers in a number of other nations do on the middle and high school level (French, 2003). The lack of coherent vision of how

to educate today's children produces unfocused curricula and textbooks that influence teachers to implement unfocused learning goals (Schmidt, McKnight, & Raizen, 1996). According to the Third International Mathematics and Science Study, "...science standards in the USA lack the coherence, focus, and level of demand that are prevalent across the high performing countries of the world" (Valverde & Schmidt, 2000, p.652). The same study indicated that by the eighth grade, U.S. students scored only slightly above the national average in science among the 41 countries involved. Although it is virtually impossible to isolate the exact reasons for the inadequate performance by these middle school students, the message that this assessment carries is that our current science education in the United States is failing to provide our students with the comprehensive science education that they need to thrive in a highly competitive and technical world.

One proposed way to address these issues is to prepare students to become excellent active learners (Wilke & Straits, 2005), who are able to transfer learning in school to the various unpredictable circumstances they face in their outside lives. Student background experiences, from sources other than their educational realms, shape what a student truly believes about the world around them (Unal &

Akpinar, 2006). Much of the traditional education that is currently implemented in United States' science classrooms have failed to produce these adaptive outcomes, which has resulted in a decline in student interest and motivation in science. Studies of teaching and learning in science classrooms reported that most teachers are still using traditional, didactic methods (Harms & Yager, 1980, Seymour, 2002; Unal & Akpinar, 2006). In many cases, the teacher lectures, providing minimal regard for the students' previous conceptions. Students are not engaged in the lessons and are passive learners of the science concepts. Students become less involved in the learning process and interest and motivation is lost. Consequently, American students continue underperforming in science (Martin et al, 2004; Parker & Gerber, 2000; Roth et al, 2006; Stigler & Hiebert, 1999).

Science educators need to provide inquiry-based instruction for students to become engaged in an active learning process that will increase motivation and gain a firm grasp of scientific principles (Carlson, 2003). Efforts must be made in order to change the focus from a traditional, teacher-centered classroom to an inquiry-based, student-centered classroom. These efforts promote an increase in student interest, motivation and achievement

in the science classroom. A continuous growing body of evidence correlates inquiry-based science instruction with an increase in achievement (Escalada & Zollman, 1997; Freedman, 1997, 2001; Johnson, Kahle, & Fargo, 2006; Kahle, Meece, & Scantlebury, 2000; Mattern & Schau, 2002; McReary, Golde, & Koeske, 2006; Morrell & Lederman, 1998; Okebukola, 1987; Oliver-Hoyo & Allen 2005; Parker & Gerber, 2000; Tamir & Glassman, 1971).

Inquiry-based instruction has been in the field of science education for several decades. Tamir and Glassman (1971) performed a controlled study, in which the achievement of biology students who studied an inquiry-based curriculum was compared with that of students who studied a traditional one. In this study both quantitative and qualitative comparisons were made between twelfth grade students working towards the inquiry-oriented BAGRUT examination,  $n=142$ , and a comparison sample,  $n=60$  who studied for the traditional BAGRUT examination. The quantitative measure was the practical BAGRUT test, whereas the qualitative measure was through direct observation of the students and informal conversation with them while they were working on the investigation. Using a 100-point scale, the mean scores of the inquiry-oriented and traditional samples were 72.9 (S.D.=11.2) and 55.2

(S.D.=16.3), respectively. The overall difference was statistically significant at 1.08 standard deviations. It was concluded that the students who had studied the inquiry-based curriculum achieved higher in solving open-ended problems using experimental procedures in the laboratory.

Shymansky, Kyle, and Alport (1983) summarized the results of a quantitative synthesis of the retrievable effects of primary research dealing with new science curricula on student performance. The new science curricula emphasized inquiry-based instruction, which included the nature, structure, and processes of science, integrated laboratory activities as an integral part of the class routine, and emphasized higher cognitive skills and appreciation of science. Utilizing meta-analysis (Glass, 1976), the study synthesized the results of 105 experimental studies involving more than 45,000 students. There were a total of 27 different inquiry-based science curricula involving one or more measures of student performance. Data were collected for 18 a priori selected student performance measures. Across all new science curricula, students exposed to inquiry-based science curricula performed better than students in traditional courses in achievement, analytic skills, process skills,

and related skills, as well as developing a more positive attitude toward science. On a composite basis, the average student in the inquiry-based science curricula exceeded the performance of 63% of the students in traditional science courses. The results of this meta-analysis revealed positive patterns of student performance in inquiry-based science curricula.

Tamir, Stavy, and Ratner (1998) indicated that inquiry-based instruction is feasible and desirable. The performance of three groups of 12<sup>th</sup> grade students; aged 16-17 was compared. Group A (n=22) specializing in physics and/or chemistry studied a conventional course that did not emphasize inquiry-based instruction throughout the curriculum. Group B (n=52) specializing in biology studied a course that emphasized inquiry-based instruction. Group C (n=50) studied the same biology course, but in addition, studied basic concepts of scientific inquiry. The early stages of the explicit instruction given to Group C included theoretical as well as concrete inquiry tasks, in familiar areas of subject matter. These tasks served to impart a set of formal concepts related to scientific inquiry, allowing students to gain the ability to cope with laboratory inquiry in a variety of areas. Two tasks served as dependent variables. Group A had the lowest scores,

about one standard deviation behind Group B. Group B, in turn, fell 1 standard deviation behind Group C. It was concluded that explicit instruction of inquiry is advantageous.

Chang and Mao (1999) examined the comparative efficiency of inquiry-based group instruction and traditional teaching methods on junior high school students' achievement and attitudes toward earth science. Their study was a nonequivalent control group quasi-experimental design involving 16 intact classes. The treatment group consisted of 319 students and received inquiry-based group instruction. The control group consisted of 293 students and received traditional instruction. Data collection instruments included the Earth Science Achievement Test and the Attitudes Toward Earth Science Inventory (Mao & Chang, 1997). A multivariate analysis of covariance suggested that the students in the experimental group had significantly higher achievement scores than did students in the control group. Furthermore, there were statistically significant differences in favor of the inquiry-based group instruction on student attitudes toward the subject matter.

Kahle, Meece, and Scantlebury (2000) examined the influence of various inquiry-based teaching methods on the

achievement of urban African-American 7th and 8th grade middle school science students. Science classes of eight teachers who had participated in the professional development of Ohio's statewide systemic initiative (SSI) were matched with classes of 10 teachers who had not participated. Data were gathered using group-administered questionnaires and achievement tests that were specifically designed for Ohio's SSI. Analyses indicated that teachers who frequently used inquiry-based teaching methods positively influenced the students' science achievement and attitudes, especially for boys.

Johnson, Kahle, and Fargo (2006) demonstrated that using inquiry-based methods positively affected student achievement. A longitudinal cohort design involved collecting scores on the Discovery Inquiry Test (DIT) in Science during the 3 years of the study. Effective inquiry-based teaching was identified through a series of classroom observations using the Local Systemic Change Classroom Observation Protocol (Horizon Research, 1999). This study found that effective inquiry-based teaching increases student achievement and closes achievement gaps for all students.

For many years, the science education community has advocated the use of inquiry-based instruction in science

classrooms. Many of the current science-education reform efforts are still advocating for the transition from traditional instruction to inquiry-based instruction using new and innovative curricula. In addition, continuous growing body of evidence correlates inquiry-based science instruction with an increase in achievement. Research supports the idea that continuous efforts must be made in order to provide student-centered, inquiry-based science classrooms for all students. These constant efforts promote an increase in student interest, motivation and achievement in the science classroom.

Trends in International Mathematics and Science Study 2007  
(TIMSS)

Trends in International Mathematics and Science Study (TIMSS) 2007 is the fourth since 1995, in a continuing cycle of internationally comparative assessments dedicated to improving teaching and learning in mathematics and science for students around the world. The International Association for the Evaluation of Educational Achievement (IEA) developed and implemented TIMSS at the international level. TIMSS is administered every four years at the fourth and eighth grades, providing data about trends in mathematics and science achievement over time. TIMSS was designed to investigate student learning of mathematics and

science and the way in which educational systems, schools, teachers, and students influence the learning opportunities and experiences of individual students. The goal is to provide comparative information about educational achievement across countries to improve teaching and learning in mathematics and science.

The TIMSS 2007 is the most recent in an ambitious series of international assessments. The TIMSS involved approximately 425,000 students from 58 countries around the world. TIMSS 2007 is designed to align broadly with mathematics and science curricula in the participating countries. The results, therefore, suggest the degree to which students have learned mathematics and science concepts and skills likely to have been taught in school. TIMSS also collects background information on students, teachers, and schools to allow cross-national comparison of educational contexts that may be related to student achievement.

In the United States, TIMSS 2007 was administered between April and June 2007. The United States sample included both public and private schools, randomly selected and weighted to be representative of the nation. In total, 257 schools and 10,350 students participated at grade four, and 239 schools and 9723 students participated at grade

eight. The overall weighted school response rate in the United States was 70% at grade four before the use of substitute schools and 89% with the inclusion of substitute schools. At grade 8, the overall weighted school response rate before the use of substitute schools was 68% and 83% with the inclusion of substitute schools. Detailed information on sampling, administration, response rates, and other technical issues are included in the *TIMSS 2007 Technical Report* (Olson, Martin, and Mullis, 2008).

The TIMSS science assessment was designed along two dimensions: the science topics or content that students are expected to learn and the cognitive skills students are expected to have developed. The content domains covered at grade four are life science, physical science, and earth science. At grade 8, the content domains are biology, chemistry, physics, and earth science. The cognitive domains in each grade are knowing, applying, and reasoning (Appendix A). Example items from the TIMSS science assessment are included in appendix B of Gonzales, Williams, Jocelyn, Roey, Kastberg, & Brenwald (2008).

The proportion of items devoted to a domain, and therefore the contribution of the domain to the overall science scale score, differs somewhat across grades. For example, at grade 4 in 2007, 37% of the TIMSS 2007 science

assessment focused on the physical science domain, while at grade 8, 46% of the assessment focused on the analogous chemistry and physics domains. The proportion of items devoted to each cognitive domain is similar across grades.

In addition, within a content or cognitive domain, the makeup of items, in terms of difficulty and form of knowledge and skills addressed, differs across grade levels to reflect the nature, difficulty, and emphasis of subject matter encountered in school. *The TIMSS 2007 Assessment Frameworks* (Mullis, Martin, Rudock, O'Sullivan, Arora, & Erberber, 2005) provides a more detailed description of the content and cognitive domains assessed in TIMSS 2007. The development and validation of the science cognitive domains is detailed in IEA's *TIMSS 2003 International Report on Achievement in the Science Cognitive Domains: Findings From a Developmental Project* (Mullis, Martin, & Foy, 2005).

TIMSS 2007 provides an overall science scale score as well as content and cognitive domain scores at each grade level. The science scale is from 0 to 1,000, and the international mean score is set at 500, with an international standard deviation of 100. The scaling of data is conducted separately for each grade and each content domain. While the scales were created to each have a mean of 500 and a standard deviation of 100, the subject

matter and the level of difficulty of items necessarily differ between the assessments at both grades. Comparability over time is established by linking the data from each assessment to the data from the assessment that preceded it. Appendix A of Gonzales et al., (2008) provides more information on how the TIMSS 2007 scale was created.

TIMSS 2007 provides a large-scale, comparative study of education in the United States and the world that can be utilized to examine our educational system, scrutinize improvement initiatives and evaluate proposed standards and curricula. According to current research, there is considerable agreement among experts that the goal of science instruction is to create learning experiences in which students are challenged to think deeply and to understand and apply concepts to new situations. TIMSS 2007 contains a huge amount of information about school systems, as well as the performance of their students. One of the important considerations in the design and implementation of TIMSS 2007 was to produce a full database that contained all of the available data collected from the participating countries and to make these data available to educational researchers around the world. Many of TIMSS 2007 published results generate new questions, which must be addressed to understand

the functioning of the school systems. Using the database, anyone who is interested can look at the same research questions from different research perspectives or investigate different research questions of interest and importance to the researcher.

#### Summary

Science educators are continuously working to improve science education. As the literature reveals, inquiry-based teaching has a decades-long and persistent history as the central method of good science pedagogy. Inquiry-based instruction employs the principles of constructivism, where science is a dynamic process and not just a body of knowledge. It is recognized that leading science organizations, such as the American Association for Advancement of Science (AAAS) and the National Research Council (NRC), stress the inclusion of inquiry-based science instruction into school science programs and curriculum. Inquiry-based instruction helps students achieve science understanding by combining scientific knowledge with reasoning and thinking skills (National Research Council, 2000). A continuous growing body of evidence correlates inquiry-based science instruction with an increase in achievement (Escalada & Zollman, 1997; Freedman, 1997; Johnson, Kahle, & Fargo, 2006; Kahle,

Meece, & Scantlebury, 2000; Mattern & Schau, 2002; McReary, Golde, & Koeske 2006; Morrell & Lederman, 1998; Okebukola, 1987; Oliver-Hoyo & Allen 2005; Parker & Gerber, 2000). Therefore, it is important that science educators give priority to the implementation of inquiry-based learning opportunities.

The consensus, along with research evidence is a clear directive for the inclusion of inquiry-based science instruction in every school. Currently, there are concerns regarding the implementation of inquiry-based instruction into the classroom. The use of inquiry-based instruction in classroom practice may not be commensurate with the emphasis of inquiry in science education literature (Aoki, Foster, & Ramsey, 2005). Studies of teaching and learning in science classrooms reported that most teachers are still using traditional, didactic methods (Harms & Yager, 1980; Seymour, 2002; Unal & Akpınar, 2006). Additionally, American students continue underperforming in science (Martin et al, 2004; Parker and Gerber, 2000; Roth et al, 2006; Stigler & Hiebert, 1999).

This study examined the relationship between teacher preparedness to teach science content and their instructional practices in the science classroom to the science achievement of eighth grade science students in the

United States as demonstrated by the 2007 Trends in International Mathematics and Science Study (TIMSS 2007). Specifically, this study investigated the orientation of teacher preparedness to teach biology, chemistry, physics, and earth science and the implementation of inquiry-based instruction to eighth grade students. Additionally, the identification of teachers' preparedness in relation to the use of inquiry-based instructional practices in the science classroom will be explored. Finally, a correlation between the teachers' implementation of inquiry-based instructional practices in science to United States eighth grade students' achievement in science as demonstrated on the TIMSS 2007 was conducted.

Chapter 3 will address the research methodology that frames this quantitative study and guides the research procedures. A description of the research method and design, sampling frame, and data collection procedures are presented. The data analysis process is also discussed.

## CHAPTER III

### RESEARCH METHODOLOGY

The data of The Trends in International Mathematics and Science Study (TIMSS) 2007 was used in this study. TIMSS 2007 is a cross-national comparative study of the performance and schooling contexts of fourth and eighth grade students in mathematics and science. TIMSS 2007 was the fourth in a cycle of internationally comparative assessments dedicated to improving teaching and learning in mathematics and science for students around the world. The International Association for the Evaluation of Educational Achievement (IEA) coordinated TIMSS 2007, with national sponsors in each participating jurisdiction. In the United States, TIMSS was sponsored by the National Center for Education Statistics (NCES), in the Institute of Education Sciences at the United States Department of Education. IEA developed TIMSS to measure trends in students' mathematics and science achievement.

TIMSS 2007 was particularly well suited for this research study for several reasons. First, TIMSS 2007 was the largest, most comprehensive, and most rigorous international study of schools and students ever conducted (Gonzales et al, 2008). TIMSS 2007 provided data from half a million students from 48 countries. Second, TIMSS 2007

was designed to investigate extensive background information that addresses concerns about the quantity, quality, and content of instruction. Third, TIMSS 2007 offered an excellent opportunity to create reliable and valid measures of instructional practices to answer the questions proposed by this study.

This study focused on the implementation of the principles of inquiry-based pedagogy on the science instruction of eighth grade students in the United States. This quantitative study seeks to answer the following questions:

- 1) What is the orientation of science teachers, with respect to their preparedness to teach specific science content to eighth grade science students?
- 2) What is the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect to their self-reported instructional practices in teaching science to eighth grade science students?
- 3) What, if any, relationship exists between teachers' beliefs about preparedness to teach science content and their self-reported instructional practices in teaching science to eighth grade science students?

4) What, if any, relationship exists between student achievement in science and:

- a. Teachers' beliefs about preparedness to teach science content to eighth grade science students.
- b. Teachers self-reported instructional practices in teaching science to eighth grade science students.

This chapter addressed the research methodology that frames this quantitative investigation and guides the research procedures. The first section outlined the sampling design. The second section delineated the data collection procedure. The third section described the technical considerations that were addressed when analyzing the data. The fourth section explained the statistical analysis and treatment of the data.

#### Sampling Design

In the United States, the target populations of students corresponded to the fourth and eighth grades. This study focused only on eighth grade. The TIMSS 2007 sample design, which consisted of a set of specifications for the target and survey populations, sampling frames, survey units, sample selection methods, sampling precision, and sample sizes. The sample design intended to ensure

that the TIMSS 2007 survey data provide accurate information of national student populations.

#### *Sample Selection Method*

The TIMSS sampling protocol was designed to yield a sample that would be representative of students across the countries. According to Joncas (2008), the student sampling selection method used in the TIMSS 2007 is a systematic, three-stage stratified cluster sampling technique. This was performed by first randomly selecting schools and then from within those schools, randomly selecting classes, followed by selecting students. "This sampling method is a natural match with the hierarchical nature of the sampling units, with classes of students within selected schools" (Joncas, 2008). Joncas (2008) further explained that all participants consistently followed the sampling method specified by the TIMSS 2007 sample design with minimum deviations. This ensured that quality standards were maintained for all participants, avoiding the possibility that differences between countries in survey results could be attributable to the use of different sampling methodologies (Joncas, 2008).

#### *School Stratification*

The sample design utilized by the TIMSS 2007 assessment is a three-stage stratified cluster sample.

School stratification was employed to improve the efficiency of the sample design and to ensure appropriate representation of specific groups in the sample (Joncas, 2008). According to Joncas (2008), the United States sampling frames was implicitly stratified by type of school (public and private), region of country (northeast, south east, mid-west and west), Community type (8 categories), and minority status (above or below 15% minority of the student population). There were 128 implicit strata. Joncas (2008) explained that when this method is used, more reliable estimates will be the result. Schools from the same implicit stratum tend to have similar science achievement (Joncas, 2008).

*First Stage Sampling Units: Schools*

In order to obtain school samples that were representative of the student populations, The National Research Coordinators (NRC) of each participating country provided information about all schools where eighth grade students could be tested. Using a sampling frame based on the 2006 National Assessment of Educational Progress (NAEP) school sampling frame, the first-stage sampling units consisted of individual schools selected with probability proportionate to size (PPS)(Joncas, 2008). The measure of size was defined as the estimated number of students

enrolled in the target grade, average student enrollment per grade, the number of classrooms in the target grade, or the student enrollment in the school (Joncas, 2008). The NRC also collected information describing school characteristics used for stratification purposes, such as type of school and demographic information. The NRC also collected information on whether or not that school already was sampled for a study other than TIMSS, because an overlapping control was required between TIMSS 2007 and other international studies Joncas (2008). Data for public schools were taken from the Common Core of Data (CCD), and data for private schools were taken from the Private School Universe Survey (PSS).

*Second Stage Sampling Units: Classes*

The second-stage sampling units were intact mathematics classrooms within sampled schools. Schools provided lists of the eighth grade classrooms. Joncas (2008) explains that within schools, classrooms with fewer than 15 students were placed into pseudo-classrooms, so that each classroom on the school's classroom sampling frame had at least 20 students. Joncas (2008) further explains that an equal probability sample of two classrooms was identified from the classroom frame for the school. In schools where there was only one classroom, this classroom

was selected with certainty (Joncas, 2008). At the eighth-grade level, 253 pseudo classrooms were created, of which 58 were included in the final classroom sample. Countries were required to randomly select a minimum of one eligible classroom per target grade per school from a list of eligible classrooms prepared for each target grade (Joncas, 2008). Furthermore, countries were encouraged to select more than one eligible classroom per target grade per school. Given the nature of the sampling units in TIMSS 2007, listing all classes, along with the class sizes, within sampled schools that agreed to participate in the study was the only requirement for building the class-sampling frame (Joncas, 2008). This list included all regular classes, in addition to any types of special education classes. Finally, within sampled classes, all students were listed.

*Third Stage Sampling Units: Students*

The third-stage sampling unit was students within sampled classrooms. All students in a sampled classroom were to be selected for the assessment. Joncas (2008) explained that the overall sample design for the United States was intended to approximate a self-weighting sample of students as much as possible, with each eighth grade student having equal probability for selection. Detailed

information on sampling is provided in Olson, Martin, and Mullis (2008).

#### Data Collection Procedure

This study examined the instructional experiences and science achievement of a national sample of a target population of 2007-2008 eighth grade science students in United States Schools. The information on instruction came from the TIMSS 2007-2008 survey of teachers, which collected questionnaires from the 687 science teachers of 7,377 eighth grade students enrolled in public and private schools across the United States. These questionnaires asked about characteristics of the classes tested in TIMSS 2007; pedagogic approach, instructional time, materials and activities for teaching science and promoting students' interest in the subject; use of computers and the internet; assessment practices; and home-school connections. They also asked teachers their views on their opportunities for collaboration with other teachers and professional development, and for information about themselves and their education and training.

The students, who participated in the TIMSS 2007, were carefully selected to represent all students in their respective nations. International technical review committees scrutinized the entire assessment process to

ensure its adherence to established standards. An international curriculum analysis was carried out prior to the development of the assessments to ensure that the tests reflected the math and science curricula of the variety of TIMSS 2007 countries and did not over-emphasize information taught in only a few countries. International monitors carefully checked the test translations and visited many classrooms while the tests were being administered in the 48 countries to make sure the instructions were properly followed. Testing occurred two to three months before the end of the 2006-2007 school year. More elaborate information is provided in Olson, Martin, and Mullis (2008).

#### Technical Considerations

The sample design was intended to ensure that the TIMSS 2007 survey data provide accurate and efficient estimates of national student populations. Three critical features in the TIMSS data collection were addressed when analyzing the data: (1) sample weights, (2) cluster sampling and design effect, and (3) plausible value and scaling procedures.

#### *Sampling Weights*

The TIMSS 2007 National Research Coordinator (NRC) of each participating country was responsible for implementing

the sample design, including documenting every step of the sampling procedure for approval by the TIMSS and PIRLS International Study Center prior to implementation (Williams et al., 2009). TIMSS 2007 participants were expected to ensure that the national defined populations included at least 95% of the national desired populations of students (Williams et al., 2009). TIMSS 2007 used a three-stage stratified cluster sampling technique, which resulted in students having an unequal, but known, probability of selection (Williams et al., 2009). Therefore, any analysis of the data must use the proper weights to correct for these sampling biases and to enable the researcher to obtain sound, nationally representative estimates to draw conclusions about the population. Since this study is limited to only United States students, Houseweight, (HOUWGT) will be used (Williams et al., 2009). This weight is calculated by taking into account the stratification or disproportional sampling of the subgroups, adjustment for non-response, and the selection probability of each student (Williams et al., 2009). Failure to apply appropriate weights would result in biased population estimates. A detailed description is provided in Olson, Martin, and Mullis (2008).

### *Sampling and Design Effect*

Standard statistical analysis programs, including SPSS, assume that data are collected from a simple random sampling design. TIMSS 2007 did not use a simple random sampling, but gathered data using a three-stage stratified cluster design (Joncas, 2008). The United States sample design within schools consisted of an equal probability sample (Joncas, 2008). Once the school was selected, scores from one classroom within that school were used in the study. All eligible students in the classroom were designated to be in the sample. In total, 239 eighth-grade schools and 7,377 eighth grade students participated for the United States (Joncas, 2008). This procedure ensured that all sub-populations in the sample were proportionately represented, however complex sampling designs make the task of computing standard errors to quantify sampling variance more difficult (Joncas, 2008). The result is a design effect. If this design effect is not considered in the analysis, erroneous decisions in inferential significance testing will result, because a smaller standard of error from simple random sample is used in analysis when a larger standard error from cluster sample is required (Joncas, 2008).

In order to correct for the design effect, a Jackknife Repeated Replication (JRR) developed through WESVAR was implemented. The JRR procedure provides an unbiased estimate of the statistic of interest by repeatedly selecting subsets of the sample from which to calculate the statistic (Williams et al., 2009). The variability of these estimates was used to estimate the sampling variance for the statistic. This variance was the sum of the squared differences of the weighted total for each of the replicates and the weighted total for the full sample (Williams et al., 2009). Seventy-five replicate weights were used to compute statistics of interest in TIMSS 2007 (Williams et al., 2009). Details on the procedures used can be found in the WesVar 4.3 User's Guide (Westat, 2007).

#### *Plausible Value and Scaling Procedures*

TIMSS 2007 was designed to produce population estimates on how various populations of students collectively performed on its proficiency scales and subscales in science. TIMSS 2007 did not estimate individual student scores in science. To keep the testing burden to a minimum, and to ensure broad subject-matter coverage, the TIMSS 2007 assessment design was based on Balanced Incomplete Block (BIB) spiraling of assessment items (Williams et al., 2009). Each student completed only

a sample of items from the total collection of assessment items. No student responded to all of the assessment items. This permits an increase of content-area without increasing the students' assessment time (Williams et al., 2009). Since not all students were given the same questions, during the scaling process, plausible values were estimated to account for the increased measurement error. A more technical description can be found in Olson, Martin, and Mullis (2008).

In TIMSS 2007, total and scale scores were estimated for each student using an item response theory (IRT) model. IRT scaling provided estimates of item parameters, such as difficulty, that define the relationship between the item and the underlying variable measured by the test (Williams et al., 2009). IRT quantifies what the true performance of a student might have been, had it been observed. Parameters of the IRT model are established as well as scales for each content area and cognitive domain specified in the assessment framework (Williams et al., 2009). With IRT, the difficulty of each item is deduced using information about how likely it is for students to get some items correct versus other items. Once the difficulty of each item is determined, the ability of each student can be estimated even when different students have been

administered different items (Williams et al., 2009). A detailed description is provided in Olson, Martin, and Mullis (2008).

#### Variable Selection and Statistical Analysis of Data

TIMSS 2007 teacher questionnaires contained numerous items representing constructs of primary concern to this study (Appendix B). TIMSS 2007 was not designed to specifically measure the preparedness, use, or beliefs of didactic and inquiry-based instruction of the teacher population. The specific instructional variables and relationships among variables examined in this report were selected because of the theoretical interests of this study. In order to eliminate bias in identification of variables for this study, 33 variables representing instructional practices that characterize both didactic and inquiry-based approaches, as recommended by the National Science Education Standards (NSES) and the framework outlined in the literature review were extracted from the teacher questionnaire. The instructional variables included various learning objectives, methods of instruction, and beliefs about learning science concepts. Instructional methods were measured by responses to questions about the relative roles of computers, experiments, lectures, discussions, group work,

individualization, homework, and assessment. For the purpose of content validity, nine secondary science teachers, with teaching experience, participated in the identification of the thirty-three extracted variables as either didactic or inquiry-based (Appendix C). The criteria for selection of variables were based on a 67% agreement of variables being identified as either didactic or inquiry-based. As a result, ten variables were identified from the teacher questionnaire as being representative of inquiry-based instruction and five variables were identified as being representative of didactic instruction.

A correlation analysis was used to determine if a relationship existed between eighth grade science teachers' main area of study and their self-reported beliefs on preparedness to teach specific science content areas. Another correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and their self-reported instructional practices. Another correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and

eighth grade student science achievement. A final correlation analysis was used to determine if a relationship existed between teachers' self-reported instructional practices in teaching science to eighth grade students and eighth grade science achievement.

#### Summary

The research method and design, sampling frame, and data collection procedures have been presented in this chapter. In addition, the instrument that was used in the study and the data analysis process has been discussed. Chapter 4 presents the data analysis procedures and results. The sections will include 5 purposes. Quantitative data results from the descriptive analysis of teachers' characteristics are examined. A correlation analysis is used to determine if a relationship existed between eighth grade science teachers' main area of study and their self-reported beliefs on preparedness to teach specific science content areas. A second correlation analysis is used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and their self-reported instructional practices. A third correlation analysis is used to determine if a relationship existed between eighth grade

science teachers' self-reported beliefs about their preparedness to teach specific science content areas and eighth grade student science achievement. A fourth correlation analysis is used to determine if a relationship existed between teachers' self-reported instructional practices in teaching science to eighth grade students and eighth grade science achievement.

## CHAPTER IV

### DATA AND ANALYSIS

The purpose of this study was to examine the relationship between teachers' self-reported preparedness for teaching science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated by TIMSS 2007. Six hundred eighty-seven eighth grade science teachers in the United States representing 7,377 students responded to the TIMSS 2007 questionnaire about their instructional preparedness and their instructional practices.

This quantitative study sought to answer the following questions:

1. What is the orientation of science teachers, with respect to their preparedness to teach specific science content to eighth grade science students?
2. What is the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect to their self-reported instructional practices in teaching science to eighth grade science students?
3. What, if any, relationship exists between teachers' beliefs about preparedness to teach science content

- and their self-reported instructional practices in teaching science to eighth grade science students?
4. What, if any relationship exists between student achievement in science and:
- a. Teachers' beliefs about preparedness to teach science content to eighth grade science students?
  - b. Teachers' self-reported instructional practices in teaching science to eighth grade science students?

Quantitative data were reported according to five purposes. Descriptive analysis of teachers' characteristics examined several dimensions and provided an accurate showcase of the population from which the sample was derived. A correlation analysis was used to determine if a relationship existed between eighth grade science teachers' main area of study and their self-reported beliefs on preparedness to teach specific science content areas. A second correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and their self-reported instructional practices. A third correlation analysis was used to determine if a

relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and eighth grade student science achievement. A final correlation analysis was used to determine if a relationship existed between teachers' self-reported instructional practices in teaching science to eighth grade students and eighth grade science achievement.

#### Quantitative Descriptive Analysis of Sample Population

Descriptive statistics from TIMSS 2007 showed that 100% of the sample population was from eighth grade integrated science courses. Descriptive analysis of the eighth grade teachers' characteristics examined several dimensions and provided statistics to highlight the nature of the population from which the sample was derived. The highest level of formal education, the teachers' indication of having a teaching license or certificate, and the teachers' main area of study was explored. The teachers' level of experience based on the number of years taught was examined. The teachers' self-reported beliefs on preparedness to teach specific science content areas were investigated. The teachers' self-reported instructional practices in the science classroom were examined. These

analyses display the characteristics of the sample population.

The highest level of formal education, the teachers' indication of having a teaching license or certificate, and teachers' main area of study was explored. Thirty-seven percent earned only a Bachelor's degree, while 63% held a Master's degree or higher. Ninety-seven percent of the teachers in the sample population have a teaching license or certificate. The identification of the teachers' major or main area of study was indicated as biology, physics, chemistry, and/or earth science. The sample population showed 43.6% of the teachers' main area of study was in biology, 18.3% in chemistry, 17.6% in earth science, and 7.8% in physics. Table 1 provides specific data concerning the teachers' main area of study.

Table 1

*Summary of Teachers' Major or Main Area of Study*

<b>Variable</b>	<b>N</b>	<b>Percentage Yes</b>	<b>Percentage No</b>
Biology	6512	43.6	56.4
Physics	6405	7.8	92.2
Chemistry	6468	18.3	81.7
Earth Science	6505	17.6	82.4

- Notes: 1. N is actual size  
 2. Houseweight applied to percentage

In the teacher questionnaire, teachers indicated the total number of years they have been teaching. The number

of years that teachers taught was recorded in groups of one to five years; six to 10 years; 11 to 15 years; 16 to 20 years; 21 to 25 years; and more than 26 years. Numerical categories were assigned one to six, respectively. The sample population showed more teachers with 1 to 5 years of experience than any other age cluster (29.0%).

Approximately 22% of the teacher population taught 6 to 10 years. This information was summarized in Table 2.

Table 2

*Summary of the Number of Years Taught*

<b>Years of Teaching</b>	<b>N</b>	<b>Percentage</b>
1 to 5	1875	29.0
6 to 10	1399	21.7
11 to 15	973	15.0
16 to 20	760	11.8
21 to 25	667	10.3
26 and over	788	12.2

- Notes: 1. 11.4% of the participants did not respond to this question  
 2. N is actual size  
 3. Houseweight applied to percentage

The first question addressed by this study was to determine the orientation of science teachers, with respect to their preparedness to teach specific science content to eighth grade science students. The teachers' self-reported beliefs on preparedness to teach specific science content areas were investigated. In the teacher's questionnaire (Appendix B), teachers responded to how well they felt

prepared to teach 23 specific concepts in the areas of biology, chemistry, physics and earth science. There were seven biology concepts, five chemistry concepts, six physics concepts, and five earth science concepts. The responses were scored on a four-point, Likert Scale as not applicable; not well prepared; somewhat prepared; very well prepared; and were assigned scores of 0, 1, 2, and 3, respectively. The means from each subject area was recorded. The means ranged from 2.21 to 2.42. Data indicated that teachers perceived more than "Somewhat prepared" to teach each content area. Table 3 displays the means for teachers' beliefs of preparedness to teach specific content areas.

Table 3

*Summary of Teachers' Beliefs of Preparedness to Teach Specific Science Content Areas*

<b>Content Area</b>	<b>N</b>	<b>Mean</b>	<b>Standard Deviation</b>
Biology	6175	2.21	.50
Chemistry	6260	2.26	.46
Physics	6212	2.42	.53
Earth Science	6299	2.23	.46

- Notes: 1. N is actual sample size  
 2. Houseweight has been applied to descriptive statistics

The second question addressed by this study was to determine the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect

to their self-reported instructional practices. According to the theoretical framework presented in this paper, teachers who value inquiry-based instruction as a means for student learning engage students in making observations; pose questions; review what is already known in regards to experimental evidence; use tools to gather, analyze, and interpret data; propose answers explanations, and predictions; communicate the results; identify assumptions; use critical and logical thinking; and consider alternative explanations; process information, communicate with groups, coach student actions, facilitate student thinking, model the learning process, and provide flexible use of materials (National Research Council (NRC), 1996 p. 23).

By contrast, teachers who value didactic instruction conceptualize instruction as the transmission of facts to students, who are seen as passive receptors. Didactic instruction typically uses lecture format and instructs the entire class as a unit. Knowledge is presented as fact where students' prior experiences are not perceived as important. Moreover, instruction does not provide students with opportunities to experiment with different methods to solve problems, but primarily uses a drill and practice format with a foundation on the use of textbooks (Smerdon, Burkam, & Lee, 1999).

TIMSS 2007 teacher questionnaires (Appendix B) contained numerous items representing constructs of primary concern to this study. TIMSS 2007 was not designed to specifically measure the preparedness, use, or beliefs of didactic and inquiry-based instruction of the teacher population. The specific instructional variables and relationships among variables examined in this report were selected because of the theoretical interests of this study. In order to eliminate bias in identification of variables for this study, 33 variables representing instructional practices that characterize both didactic and inquiry-based approaches, as recommended by the National Science Education Standards (NSES) and the framework outlined in the literature review were extracted from the teacher questionnaire. The instructional variables included various learning objectives, methods of instruction, and beliefs about learning science concepts. Instructional methods were measured by responses to questions about the relative roles of computers, experiments, lectures, discussions, group work, individualization, homework, and assessment. For the purpose of content validity, nine secondary science teachers, with teaching experience, participated in the identification of the 33 extracted variables as either

didactic or inquiry-based (Appendix C). The criteria for selection of variables were based on a 67% agreement of variables being identified as either didactic or inquiry-based. As a result, ten variables were identified from the teacher questionnaire as being representative of inquiry-based instruction and five variables were identified as being representative of didactic instruction.

<b>Variable</b>	<b>Questionnaire Number</b>	<b>Type of Instruction</b>
Observe (BT4SCSON)	17a	Inquiry
Watchdem (BT4SCSWD)	17b	Didactic
Designexp (BT4SCSDP)	17c	Inquiry
Conductexp (BT4SCSEI)	17d	Inquiry
Smallgroups (BT4SCSSG)	17e	Inquiry
Readtext (BT4SCSRM)	17f	Didactic
Memorize (BT4SCSHP)	17g	Didactic
Useformulas (BT4SCSUP)	17h	Didactic
Giveexplan (BT4SCSGS)	17i	Inquiry
Dailylives (BT4SCSDL)	17j	Inquiry
Compexp (BT4SCAPE)	22a	Inquiry
Compsimulat (BT4SCANP)	22b	Inquiry
Compskills (BT4SCASP)	22c	Didactic
Compinfo (BT4SCALI)	22e	Inquiry
Companalyze (BT4SCAPA)	22f	Inquiry

*Figure 2.* Variables identified as inquiry-based instruction or didactic instruction with 67% agreement

For the purpose of this study, the ten variables identified from the TIMSS 2007 teacher questionnaire as having the qualities of inquiry-based instruction were scored on a four-point, Likert Scale with the responses of every or almost every lesson; about half the lessons; some lessons; and never. Each were assigned values of 3, 2, 1,

and 0, respectively. The means ranged from .70 to 2.34. There were high indications ( $\underline{M}=2.35$ ) for teachers providing students opportunities to relate what they are learning in science to their daily lives and ( $\underline{M}=2.28$ ) for teachers providing students the opportunity to give explanations about something they are studying indicating the teachers used the techniques more than half the lessons they teach. Five of the ten techniques of inquiry-based instruction were between 1.0 and 2.0 indicating the teachers used the techniques greater than some lessons, but less than half the lessons they teach. There were low indications among the teachers for asking the students to do experiments, study natural phenomena, and analyze data using computers ( $\underline{M}=.70$ ,  $\underline{M}=.73$ ,  $\underline{M}=.89$ , respectively). The means for all 10 measures are reported in Table 4.

Table 4

*Summary of Descriptive Analysis of Inquiry-Based Teaching to the TIMSS 2007 Class Using a Four-Point Likert-Scale*

<b>Variable</b>	<b>N</b>	<b>Mean</b>	<b>Standard Deviation</b>
Observe (BT4SCSON)	6475	1.42	.74
Designexp (BT4SCSDP)	6502	1.22	.66
Conductexp (BT4SCSEI)	6535	1.60	.74
Smallgroups (BT4SCSSG)	6535	1.83	.76
Giveexplan (BT4SCSGS)	6535	2.28	.80
Dailylives (BT4SCSDL)	6524	2.34	.79
Compexp(BT4SCAPE)	4842	0.70	.62
Compsimulat (BT4SCANP)	4842	0.73	.66
Compinfo(BT4SCALI)	4842	1.22	.55
Companalyze (BT4SCAPA)	4837	0.89	.71

- Notes: 1. N is actual sample size  
 2. Houseweight has been applied to descriptive statistics

Teachers also responded to five variables as using techniques aligned with the qualities consistent with didactic classroom instruction. The teacher responses were scored on a four-point, Likert Scale with the responses of every or almost every lesson; about half the lessons; some lessons; and never. Each was assigned values of 0, 1, 2, and 3, respectively. The means ranged from 1.52 to 2.81. The lowest indication ( $\bar{M}=1.52$ ) among the teachers was for having the students read their textbooks or other resource materials for less than half their lessons. Four of the five techniques of didactic instruction were above 1.00, but less than 3.00 indicating the teachers used the

techniques less than half the lessons. The means for all five measures are reported in Table 5.

Table 5

*Summary of Descriptive Analysis of Didactic Teaching to the TIMSS 2007 Class Using a Four-Point Likert-Scale*

<b>Variable</b>	<b>N</b>	<b>Mean</b>	<b>Standard Deviation</b>
Watchdem (BT4SCSWD)	6502	1.76	.55
Readtext (BT4SCSRM)	6432	1.52	.81
Memorize (BT4SCSHP)	6500	1.83	.77
Useformulas (BT4SCSUP)	6505	1.60	.70
Compskills (BT4SCASP)	4834	2.19	.79

Notes: 1. N is actual sample size

2. Houseweight has been applied to descriptive statistics

#### Quantitative Correlation Analysis

In addition to investigating and describing teachers' characteristics and instructional practices from which the population was derived, the relationship between these areas was also explored. In this section, correlation analyses are presented.

#### *Results of Correlation Analyses of Eighth Grade Science Teachers' Self-Reported Beliefs about Preparedness to Teach Specific Science Content Areas and Their Self-Reported Instructional Practices*

The third question addressed in this study was what, if any, relationship exists between teachers' beliefs about preparedness to teach science content and their self-

reported instructional practices in teaching science to eighth grade science students. First, Pearson correlation coefficients for items that measured the analysis between eighth grade science teachers' self-reported beliefs for preparedness to teach specific science content areas and their self-reported use of inquiry-based instructional practices were computed. Data indicated a statistically significant positive relationship existed between teachers' self-reported use of inquiry-based instruction and preparedness to teach biology (.071), chemistry (.060), and physics (.041), respectively. There was a statistically significant negative relationship between teachers' self-reported use of inquiry-based instruction practices and preparedness to teach earth science (-.032). Teachers who indicated they have feelings of preparedness to teach biology, chemistry, and physics, respectively, indicated they use inquiry-based instructional practices more frequently. Teachers who indicated having lesser feelings of preparedness in earth science indicated they use inquiry-based instructional practices more frequently. Table 6 presents the correlation coefficients.

Table 6

*Summary of Correlation Analysis between 8<sup>th</sup> Grade Science Teachers' Self-Reported Beliefs for Preparedness to Teach Specific Science Content Areas and their Self-Reported Inquiry-based Instructional Practices*

<b>Variable</b>	<b>Biology Preparedness</b>	<b>Chemistry Preparedness</b>	<b>Physics Preparedness</b>	<b>Earth Science Preparedness</b>
Inquiry Instruction	.071**	.060**	.089**	-.032**
N	4078	4150	4093	4183

- Notes: 1. Houseweight has been applied to all correlation statistics  
 2. \*\* p < .01

Then, Pearson correlation coefficients were computed to examine if a relationship existed between eighth grade science teachers' main area of study and their self-reported beliefs about their preparedness to teach specific science content areas. This provided the researcher with information that could help explain the relationship between teachers' beliefs about preparedness to teach science content and their self-reported instructional practices in teaching science to eighth grade science students. Table 7 presents the correlations between the eighth grade science teachers' four main areas of study and their self-reported beliefs of preparedness to teach the four specific science content areas.

Table 7

*Summary of Correlation Analysis between 8<sup>th</sup> Grade Science Teachers' Main Area of Study and their Self-Reported Beliefs on Preparedness to Teach Specific Science Content Areas*

<b>Variable</b>	<b>Biology Preparedness</b>	<b>Chemistry Preparedness</b>	<b>Physics Preparedness</b>	<b>Earth Science Preparedness</b>
Biology	.150**	.110**	-.020	-.135**
N	6060	6145	6097	6184
Chemistry	0.190	.106**	.075**	-.085**
N	6016	6101	6053	6140
Physics	.013	.046**	.180**	.045**
N	5953	6038	6010	6077
Earth Science	-.127**	-.012	.092**	.113**
N	6053	6138	6090	6177

Notes: 1. Houseweight has been applied to all correlation statistics  
 2. \*\* p < .01

Results showed all teachers' main area of study had a statistically significant positive correlation with their self-reported feelings of preparedness to teach that same science content area at the p < .01 level. There was a statistically significant positive correlation between teachers who indicated biology as their main area of study and their self-reported feelings of preparedness to teach chemistry, but a statistically significant negative correlation for feelings of preparedness to teach earth science. There was a statistically significant positive correlation between teachers who indicated chemistry as

their main area of study and their self-reported feeling of preparedness to teach physics, but a statistically significant negative correlation for feelings of preparedness to teach earth science. There was a statistically significant positive correlation between teachers who indicated physics as their main area of study and their self-reported feeling of preparedness to teach chemistry and earth science. There was a statistically significant positive correlation between teachers who indicated earth science as their main area of study and their self-reported feeling of preparedness to teach physics, but a statistically significant negative correlation for feelings of preparedness to teach biology and chemistry.

There was not a statistically significant correlation between teachers who indicated biology as their main area of study and their self-reported feelings of preparedness to teach physics. There was not a statistically significant correlation between teachers who indicated chemistry as their main area of study and their self-reported feeling of preparedness for biology. There was not a statistically significant correlation between teachers who indicated physics as their main area of study and their self-reported feeling of preparedness for

biology. There was not a statistically significant correlation between teachers who indicated earth science as their main area of study and their self-reported feeling of preparedness for chemistry. The above-mentioned correlations indicated that teachers who specify a certain science subject area as their main area of study do not necessarily give teachers a feeling of preparedness to teach all science subject areas.

*Results of Correlation Analyses between Eighth Grade Student Science Achievement and Science Teachers' Self-Reported Beliefs about Preparedness to Teach Specific Science Content Areas Practices*

The fourth question addressed in this study was two-fold with regards to student science achievement. What, if any relationship exists between eighth grade student achievement in science and teachers' self-reported beliefs about preparedness to teach science content to eighth grade science students? What, if any relationship exists between eighth grade student achievement and Teachers' self-reported instructional practices in teaching science to eighth grade science students?

To answer the first part of this question, a correlation analysis was used to determine if a relationship existed between eighth grade science teachers'

self-reported beliefs about their preparedness to teach specific science content areas and eighth grade student science achievement. Table 8 presents correlation coefficients for items that measured eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and student science achievement.

Table 8

*Summary of Correlation Analysis between 8<sup>th</sup> Grade Science Teachers' Self-Reported Beliefs on Preparedness to Teach Specific Science Content Areas and 8<sup>th</sup> Grade Student Science Achievement*

<b>Variable</b>	<b>Biology Preparedness</b>	<b>Chemistry Preparedness</b>	<b>Physics Preparedness</b>	<b>Earth Science Preparedness</b>
Student Achievement	.021	-.018	.067**	-.046
N	6175	6260	6212	6299

Notes: 1. Houseweight has been applied to all correlation statistics  
 2. \*\* p < .05

Data indicated a statistically significant positive relationship existed between physics preparedness and student science achievement with a correlation coefficient of .067 at the .05 level. There was no significant relationship between teachers' preparedness to teach biology, chemistry, and earth science respectively and student science achievement. Teachers who have feelings ranging from being "very well prepared" or "not well

prepared" to teach a specific content area do not necessarily have students achieving in science.

To answer the second part of the fourth research question, a correlation analysis was performed to determine if a relationship existed between eighth grade science teachers' self-reported individual instructional practices and eighth grade student science achievement. At the .01 level, data analysis indicated a statistically significant positive relationship existed between reading their textbooks or other resource material (BT4SCSRM), have students memorize facts and principles (BT4SCSHP), use scientific formula and laws to solve routine problems (BT4SCSUP), and using a computer for practice skills and procedures (BT4SCASP). Teachers who indicated they use the previously mentioned instructional practices infrequently were more likely to have students achieving in science. There were no other statistically significant relationships between individual instructional practices and eighth grade science achievement. In other words, teachers who frequently implement inquiry-based instructional strategies or infrequently implement didactic-based instructional strategies do not necessarily produce high achieving eighth grade students. Table 9 presents correlation coefficients for items that measured eighth grade science teachers'

self-reported, individual instructional practices and eighth grade science achievement.

Table 9

*Summary of Correlation Analysis between 8<sup>th</sup> Grade Science Teachers' Self-Reported Individual Instructional Practices and 8<sup>th</sup> Grade Student Science Achievement*

<b>Variable</b>	<b>N</b>	<b>Student Science Achievement</b>
Observe (BT4SCSON)	6475	.062
Watchdem (BT4SCSWD)	6502	.023
Designexp (BT4SCSDP)	6502	.004
Conductexp (BT4SCSEI)	6535	.049
Smallgroups (BT4SCSSG)	6535	.004
Readtext (BT4SCSRM)	6432	.109**
Memorize (BT4SCSHP)	6500	.106**
Useformulas (BT4SCSUP)	6505	.105**
Giveexplan (BT4SCSGS)	6535	-.019
Dailylives (BT4SCSDL)	6524	.001
Compexp (BT4SCAPE)	4842	-.049
Compsimulat (BT4SCANP)	4842	-.029
Compskills (BT4SCASP)	4834	.122**
Compinfo (BT4SCALI)	4842	-.049
Companalyze (BT4SCAPA)	4837	-.048

Notes: 1. Houseweight has been applied to all correlation statistics  
 2. \*\* p < .01

In addition to the previous correlation analysis, a correlation coefficient was computed to analyze the relationship between eighth grade science teachers' self-reported, inquiry-based instructional practices and student science achievement. Data indicated a statistically significant positive relationship existed between science teachers' self-reported implementation of inquiry-based

instructional practices and student science achievement with a correlation coefficient of .011 at the .01 level. Teachers who indicated more use of inquiry-based teaching practices and less use of didactic teaching practices were more likely to have students achieving in science. Table 10 presents the correlation coefficient.

Table 10

*Summary of Correlation Analysis between 8<sup>th</sup> Grade Science Teachers' Self-Reported Implementation of Inquiry-Based Instructional Practices and 8<sup>th</sup> Grade Student Science Achievement*

<b>Variable</b>	<b>N</b>	<b>Student Science Achievement</b>
Inquiry Instruction	6475	.110**

Notes: 1. Houseweight has been applied to all correlation statistics  
 2. \*\* p < .01

#### Summary

The quantitative data reported in Chapter 4 were analyzed to examine the relationship between teachers' self-reported preparedness for teaching science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated by TIMSS 2007. Quantitative descriptive analysis and correlation analysis were conducted. Of the four questions examined, descriptive analysis provided data to support the answer for question one. Data indicated

that teachers perceived more than "Somewhat prepared" to teacher each content area. To support the answer for question two, what is the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect to their self-reported instructional practices in teaching science to eighth grade science students was supported with descriptive analysis. The means were reported for ten inquiry-based teaching strategies and five didactic-based strategies. To support the answer to question three, what, if any, relationship exists between teachers' beliefs about preparedness to teach science content and their self-reported instructional practices in teaching science to eighth grade science students, a correlation analysis was utilized. Pearson correlation coefficients were used to determine the existence of relationships. The fourth question addressed in this study was two-fold concerning student science achievement. What, if any relationship exists between eighth grade student achievement in science and teachers' self-reported beliefs about preparedness to teach science content to eighth grade science students? What, if any relationship exists between eighth grade student achievement and teachers' self-reported instructional practices in teaching science to eighth grade science students? To support the answer to

both questions, a correlation analysis was utilized. Pearson correlation coefficients were used to determine the existence of relationships. Quantitative descriptive analysis and correlation analysis were conducted in Chapter 4 to provide support to answer the four questions in this study.

Chapter 5 presents conclusions drawn from the data analysis and discussions regarding the conclusions. Finally, implications for science teachers and future research are discussed, followed by a summary of the study.

## CHAPTER V

### CONCLUSION AND DISCUSSION

The primary focus of this study was to examine the relationship between teachers' preparedness to teach science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated on the TIMSS 2007 exam. Specifically, this study investigated the orientation of teacher preparedness to teach biology, chemistry, physics, and earth science and the implementation of inquiry-based instruction to eighth grade students' science achievement.

Data collection for this study produced the depth and complexity of information to answer the following research questions:

1. What is the orientation of science teachers, with respect to their preparedness to teach specific science content to eighth grade science students?
2. What is the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect to their self-reported instructional practices in teaching science to eighth grade science students?
3. What, if any, relationship exists between teachers' beliefs about preparedness to teach science content

- and their self-reported instructional practices in teaching science to eighth grade science students?
4. What, if any relationship exists between student achievement in science and:
- a. Teachers' beliefs about preparedness to teach science content to eighth grade science students?
  - b. Teachers' self-reported instructional practices in teaching science to eighth grade science students?

The following chapter is organized by first providing a summary of the procedures used in this study. Then, a discussion of the conclusions generated from the quantitative analyses of this study is presented as they related to the above-mentioned purposes. Next, implications for science teachers and the educational community is presented. The chapter concluded with suggestions for future research study based upon the results and limitations of this study.

#### Summary of Procedure

This study examined the relationship between teachers' self-reported preparedness for teaching science content and their instructional practices to the science achievement of eighth grade science students in the United States as demonstrated by TIMSS 2007. The information on teachers'

self-reported preparedness for teaching specific content and instructional tendencies was taken from the TIMSS 2007 survey of teachers. Questionnaires were collected from six hundred eighty-seven eighth grade teachers in the United States representing 7,377 students enrolled in public and private schools.

The TIMSS sampling protocol was designed to yield a sample that would be representative of students across the United States. According to Joncas (2008), the student sampling selection method used in the TIMSS 2007 is a systematic, three-stage stratified cluster sampling technique. Teachers of these students were asked to complete questionnaires about themselves pertaining to their own qualifications and experience with teaching science; pedagogic approach; assessment practices; and home-school connections.

TIMSS 2007 teacher questionnaire (Appendix B) contained numerous items representing constructs of primary concern to this study. TIMSS 2007 was not designed to specifically measure the preparedness, use, or beliefs of didactic and inquiry-based instruction of the teacher population. The specific instructional variables and relationships among variables examined in this report were selected because of the theoretical interests of this

study. In order to eliminate bias in identification of variables for this study, thirty-three variables representing instructional practices that characterize both didactic and inquiry-based approaches, as recommended by the National Science Education Standards (NSES) and the framework outlined in the literature review were extracted from the teacher questionnaire. The instructional variables included various learning objectives, methods of instruction, and beliefs about learning science concepts. Instructional methods were measured by responses to questions about the relative roles of computers, experiments, lectures, discussions, group work, individualization, homework, and assessment. For the purpose of content validity, nine secondary science teachers, with teaching experience, participated in the identification of the thirty-three extracted variables as either didactic or inquiry-based (Appendix C). The criteria for selection of variables were based on a 67% agreement of variables being identified as either didactic or inquiry-based. As a result, ten variables were identified from the teacher questionnaire as being representative of inquiry-based instruction and five variables were identified as being representative of didactic instruction.

Quantitative data were reported according to five purposes. Descriptive analysis of teachers' characteristics examined several dimensions and provided an accurate showcase of the population from which the sample was derived. A correlation analysis was used to determine if a relationship existed between eighth grade science teachers' main area of study and their self-reported beliefs on preparedness to teach specific science content areas. A second correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and their self-reported instructional practices. A third correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and eighth grade student science achievement. A final correlation analysis was used to determine if a relationship existed between teachers' self-reported instructional practices in teaching science to eighth grade students and eighth grade science achievement.

## Conclusions

Four research questions were identified at the onset of this study. Based on the quantitative analysis done in this study, results of the study are discussed with a presentation of interpretations and conclusions.

### *Summary of Teacher Characteristics*

Factors that influence teachers' practice are complex and numerous. According to Mayer, Mullens, and Moore (2000), to ensure high levels of academic achievement, teachers should have high academic skills, teaching in the field in which they received their training and have more than a few years of experience. Descriptive analyses of the eighth grade teachers' characteristics examined several dimensions and provided statistics to highlight the nature of the population from which the sample was derived. The highest level of formal education, the teachers' indication of having a teaching license or certificate, and the teachers' main area of study was explored. The teachers' level of experience based on the number of years taught was examined. The teachers' self-reported beliefs on preparedness to teach specific science content areas were investigated. The teachers' self-reported instructional practices in the science classroom were examined. These

analyses display the characteristics of the sample population.

The highest level of formal education, the teachers' indication of having a teaching license or certificate, and teachers' main area of study was explored. Thirty-seven percent earned only a Bachelor's degree, while 63% held a Master's degree or higher. Ninety-seven percent of the teachers in the sample population have a teaching license or certificate. The identification of the teachers' major or main area of study was indicated as biology, physics, chemistry, and earth science. The sample population showed 43.6% of the teachers' main area of study was in biology, 18.3% in chemistry, 17.6% in earth science, and 7.8% in physics.

In the teacher questionnaire, teachers indicated how many years they have been teaching all together. The number of years that teachers taught was reported in terms of one to five years; six to 10 years; 11 to 15 years; 16 to 20 years; 21 to 25 years; and more than 26 years. The sample population showed that most teachers, 29% had one to five years teaching experience. Approximately 22% of the teacher population taught six to 10 years. Over 50% of the teachers in the sample population had 10 or less years teaching experience.

### *Summary of Teachers' Preparedness*

The first research question addressed by this study was to determine the orientation of science teachers, with respect to their preparedness to teach specific science content to eighth grade science students. In the teacher's questionnaire (Appendix B), teachers responded to how well they felt prepared to teach 23 specific concepts in the areas of biology, chemistry, physics and earth science. There were seven biology concepts, five chemistry concepts, six physics concepts, and five earth science concepts. The means from each subject area were recorded. The means ranged from 2.21 to 2.42. The sample population showed that teachers felt more than "Somewhat prepared" to teach each content area. Teachers indicated they felt the most prepared to teach physics.

### *Summary of Teachers' Inquiry-Based Instructional Tendencies*

The second question addressed by this study was to determine the orientation of science teachers, on a continuum from didactic to inquiry oriented, with respect to their self-reported instructional practices. TIMSS 2007 teacher questionnaires (Appendix B) contained numerous items representing constructs of primary concern to this study. TIMSS 2007 was not designed to specifically measure the preparedness, use, or beliefs of didactic and inquiry-

based instruction of the teacher population. The specific instructional variables and relationships among variables examined in this report were selected because of the theoretical interests of this study. As explained in Chapter 3, the researcher identified the questions as either inquiry-based or didactic teaching instruction based on the theoretical framework of this study.

The definition of inquiry-based instruction for this study is provided by the National Science Education Standards (NSES): Inquiry-based instruction engages students in making observations; posing questions; reviewing what is already known in regards to experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; communicating the results; identifying assumptions; using critical and logical thinking; and considering alternative explanations; processing information, communicating with groups, coaching student actions, facilitating student thinking, modeling the learning process, and providing flexible use of materials. (National Research Council (NRC), 1996 p. 23)

The researcher identified ten questions as using techniques aligned with the qualities consistent with inquiry-based classroom instruction. Five of the 10

techniques of inquiry-based instruction were scored between 1.0 and 2.0 indicating the teachers used the techniques greater than some lessons, but less than half the lessons they teach. Among the teachers, the highest indications were for teachers providing students opportunities to relate what they are learning in science to their daily lives ( $\underline{M}=2.34$ ) and for teachers providing students the opportunity to give explanations about something they are studying ( $\underline{M}=2.28$ ). This indicated the teachers used these inquiry-based strategies more than half the lessons, but not for every lesson. At least 93% of the teachers indicated using all the identified inquiry-based techniques for at least some of the lessons they teach. Therefore, teachers are using inquiry-based techniques to instruct students in science that are supported by the National Research Council (NRC).

*Summary of Teachers' Didactic-Based Instructional Tendencies*

In addition to the researcher identifying ten questions as using techniques aligned with the qualities consistent with inquiry-based classroom instruction, the researcher also identified five questions as using techniques aligned with the qualities consistent with didactic classroom instruction. Didactic instruction is

defined as the transmission of facts to students, who are seen as passive receptors. This instruction typically uses lecture format and instructs the entire class as a unit. Knowledge is presented as fact where students' prior experiences are not seen as important. Moreover, instruction does not provide students with opportunities to experiment with different methods to solve problems, but primarily uses a drill and practice format with a foundation on textbooks (Smerdon, Burkam, and Lee, 1999).

In this study, four of the five techniques of didactic instruction had means that were above 1.00, but less than 3.00 indicating the teachers used the techniques less than half the lessons. Among the teachers, the lowest indication, less than half their lessons ( $\underline{M}=1.52$ ) was for having the students read their textbooks or other resource materials. This supports the NRC's notion of less emphasis on the use of textbooks as the primary means of instruction and student learning. Between 62% and 82% of the teachers indicated only using the didactic techniques for some lessons or never as opposed to using the techniques for almost every lesson or about half the lessons. This indicates that the teachers in this study are using more inquiry-based techniques, rather than didactic techniques to instruct their students in science. Moreover, as

explained in Chapter 2, these results support the NRC's view for teachers employing instruction having more emphasis on inquiry-based instructional strategies and less emphasis on didactic strategies.

*Summary of Correlation Analysis between Teachers' Beliefs about Preparedness to Teach Science Content and Their Self-Reported Instruction Practices*

The third question addressed in this study was what, if any, relationship exists between teachers' beliefs about preparedness to teach science content and their self-reported instructional practices in teaching science to eighth grade science students. First, a correlation analysis was used to determine if a relationship existed between eighth grade science teachers' main area of study and their self-reported beliefs on preparedness to teach specific science content areas. A second correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and their self-reported instructional practices.

The identification of the teachers' main area of study was indicated as biology, physics, chemistry, and earth science. The sample population showed 43.6% of the

teachers' main area of study was in biology, 18.3% in chemistry, 17.6% in earth science, and 7.8% in physics. This is consistent with Chaney (1995), who explained most middle school teachers who possess a degree in science have a degree in life sciences or biology.

The data showed all teachers' main area of study had a statistically significant positive correlation with their self-reported feelings of preparedness to teach that same science content area. In addition, data showed that teachers whose main area of study was biology, chemistry, or earth science had a statistically significant negative correlation for having feelings of preparedness for at least one science content area outside of their main area of study. Although these correlations were statistically significant, the magnitudes of the relation between the variables were weak. While these correlations were weak, the finding is consistent with Goldhaber and Brewer (1998) who found many middle school science teachers do not have a bachelor's degree or certification in the subject they are being asked to teach. Furthermore, Chaney (1995) explains that only a minority of middle school teachers possess a degree in the earth and physical sciences. This tendency could be problematic for reform efforts; because many middle school curriculums are integrated in nature, with

several science content areas per grade level (Saderholm & Tretter, 2008).

The second correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and their self-reported instructional practices. The data showed a statistically significant positive relationship existed between teachers' self-reported use of inquiry-based instruction and preparedness to teach biology, chemistry, and physics. Although this correlation was statistically significant, the magnitudes of the relation between the variables were weak. However, the correlation indicated that teachers who tend to use inquiry-based instructional practices more frequently have feelings of being prepared to teach biology, chemistry, or physics, respectively. There was a statistically significant negative relationship between teachers' self-reported use of inquiry-based instructional practices and preparedness to teach earth science. Similar to the above correlation, the magnitude of the relation between the variables were weak. However, the correlation indicated that teachers who tend to use inquiry-based instructional practices more frequently do not feel they are prepared to teach earth science.

The major trend in science education reform is emphasis for science teachers to use inquiry-based instruction. One factor that has emerged in research literature is the effect teacher preparedness has on teacher practice. Teachers are the primary means of curriculum implementation. A teacher's level of preparedness in their content area of expertise is of critical importance (Darling-Hammond, 2000). At the secondary level, studies indicate that coursework taken in subject-specific pedagogy is positively related to implementing sound pedagogy and secondary students' achievement (Chaney, 1995; Monk, 1994). Studies of science teachers' pedagogical knowledge have reported positive effects of education training on teachers' knowledge and practices (Adams & Krockover, 1997).

*Summary of Correlation Analysis between Eighth Grade Student Science Achievement and Teachers' Self-Reported Beliefs about Preparedness to Teach Science*

The fourth question addressed in this study was two-fold in regards to student science achievement. What, if any relationship exists between eighth grade student achievement in science and teachers' self-reported beliefs about preparedness to teach science content to eighth grade science students? What, if any relationship exists between

eighth grade student achievement and Teachers' self-reported instructional practices in teaching science to eighth grade science students?

To answer the first part of this question a correlation analysis was used to determine if a relationship existed between eighth grade science teachers' self-reported beliefs about their preparedness to teach specific science content areas and eighth grade student science achievement. Although the magnitude of the correlation was weak, the data indicated a statistically significant positive relationship existed between physics preparedness and student science achievement. Previous analysis showed that 7.8% of the teacher sample had indicated physics as their main area of study. In addition, teachers indicating physics as their main area of study also had a statistically significant positive relationship with having feelings of preparedness for teaching both chemistry and earth science. According to this study, physics teachers indicated feelings of being prepared to teach all science subjects except biology and it was physics teachers who indicated a statistically significant positive relationship between physics preparedness and student science achievement. These results are consistent with the findings of Goldhaber &

Brewer (1997, 2000). They found science teachers holding subject-specific degrees and therefore having the subject knowledge to teach specific science content to have a statistically positive relationship with student achievement.

To answer the second part of the fourth research question, a correlation analysis was performed to determine teachers' self-reported inquiry-based instructional practices and eighth grade student science achievement. Data indicated a weak statistically significant positive relationship existed between science teachers' self-reported implementation of inquiry-based instructional practices and student science achievement. Teachers who indicated more use of inquiry-based instruction and less use of didactic instruction were more likely to have students achieving in science. This is consistent with several other studies that has produced evidence that correlates inquiry-based science instruction with an increase in achievement (Escalada & Zollman, 1997; Freedman, 1997, 2001; Johnson, Kahle, & Fargo, 2006; Kahle, Meece, & Scantlebury, 2000; Mattern & Schau, 2002; McReary, Golde, & Koeske, 2006; Morrell & Lederman, 1998; Okebukola, 1987; Oliver-Hoyo & Allen 2005; Parker & Gerber, 2000; Tamir & Glassman, 1971). Efforts must be made in

order to change the focus from a traditional, teacher-centered classroom to an inquiry-based, student-centered classroom. These efforts could promote an increase in student interest, motivation and achievement in the science classroom.

#### Educational Implications of the Study

The current trend in science education is to adopt instructional practices that follow research on how students learn and achieve. Science educators and the National Science Standards have actively recommended using inquiry-based instruction to engage students in the processes of learning science. McReary, Golde, & Koeske (2006) emphasized the importance of inquiry-based instruction for a successful reform in science education. Furthermore, other studies have produced evidence that correlates inquiry-based science instruction with an increase in achievement (Escalada & Zollman, 1997; Freedman, 1997, 2001; Johnson, Kahle, & Fargo, 2006; Kahle, Meece, & Scantlebury, 2000; Mattern & Schau, 2002; McReary, Golde, & Koeske, 2006; Morrell & Lederman, 1998; Okebukola, 1987; Oliver-Hoyo & Allen 2005; Parker & Gerber, 2000; Tamir & Glassman, 1971). Increased attention has focused on helping science teachers to depart from traditional, didactic methods of instruction and provide

opportunities for students to become engaged in more active, meaningful, and higher-level learning.

Despite the evidence correlating inquiry-based science instruction with increased achievement, many teachers are still resistant to such changes in pedagogy. Some of the recent educational reform efforts to transition traditional science instruction into more innovative, inquiry-based programs have not been completely successful. Studies of teaching and learning in science classrooms reported that most teachers are still using traditional, didactic methods (Harms & Yager, 1980; Seymour, 2002; Unal & Akpinar, 2006). Science teachers must be adequately prepared to implement inquiry-based instruction effectively. Recommendations for ways to support science teacher's successful integration of inquiry-based instruction into science classrooms, such as ample training and preparation, support to develop a positive self-efficacy for inquiry-based instruction, and development of inquiry-based curriculum materials, all have the potential to foster positive support for science teachers. Since the use of inquiry-based instruction is imperative for science education reform and student achievement (NRC, 1996), science educators need to be adequately prepared to implement inquiry-based instruction to engage students in the process of learning science.

In view of the results, there are four major implications for educational practice. First, clear, guiding principles must support the visions of the national science education reforms and national and state science standards. Second, teacher preparation institutes must use those same guiding principles to train and prepare science teachers for effective implementation of inquiry-based instruction. Third, as science teachers orchestrate inquiry-based lessons, teacher professional development, supervision and support is needed to provide continuous growth and positive self-efficacy. The fourth implication is that curriculum developers need to provide instructional materials that are appropriate and current.

Clear, guiding principles must support the visions of the national science education reforms and national and state science standards. Science educators, researchers, and philosophers have provided multiple interpretations of inquiry. Consequently, teachers of science are left to interpret the foundation, implementation, and results of inquiry-based instruction and the effects on student learning. To help clarify, the NRC (2000) released *Inquiry and the National Science Education Standards*, however as discussed in Chapter 2, research support the notion that science educators are still unclear about what inquiry

means coupled with the uncertainty of implementing inquiry-based instruction. When teachers develop and enact their own ideas of inquiry-based instruction in their classroom practice, these conceptions may not necessarily match with the vision of the reform documents. Science teachers need to have a lucid conception of how inquiry-based instruction is implemented and take this conception to the classroom for students to be engaged in an inquiry-based learning environment. Thus, science educators, researchers, and philosophers should obtain a better conception of inquiry-based instruction.

A second implication was for teacher preparation institutes to use guiding principles to train and prepare science teachers for effective implementation of inquiry-based instruction. According to literature on science education reform, one reason reform efforts fail are the inadequate preparation for the teachers who are expected to enact specific methods of instruction (National Research Council, 1996). Pre-service teachers of science need adequate content and pedagogical knowledge where inquiry-based instruction has a dominant role in preparing them to employ inquiry-based instruction in classrooms. Teacher preparation institutes need to provide knowledge, experiences, and supervision to prepare science teachers to

design and implement inquiry-based lessons. When teachers have feelings of preparedness for inquiry-based instruction in both their content and pedagogical knowledge, science teachers are confident that they can deliver such instruction to their students (NRC, 1996b).

In addition to the importance of teacher preparation and experience, the school districts and administrators play an important role in facilitating or impeding the implementation of inquiry-based instruction in classrooms. A third implication was as science teachers orchestrate inquiry-based lessons, teacher supervision, professional development, and support is needed to provide continuous growth and positive self-efficacy. According to the NRC (1996), one reason reform efforts fail are from insufficient professional development for the teachers who are expected to enact these reform efforts. Teachers can often be subjected by reform efforts to make changes in their instruction that are beyond their knowledge-base and pedagogical understanding (Ball & Cohen, 1996; Davis, 2003). The National Standards (NRC, 2000) describe specifically how school districts can support teachers in their attempts to implement inquiry-based instruction. One way is to emphasize and focus on the changes that are called for in the standards and less emphasis on other

extraneous policies. A second way is to provide long-term and on-going support for teachers that center on a commitment to inquiry-based instruction. A third way is to provide opportunities to actively participate and interact with new ideas and understandings. Considering these three concepts, the duration in which these experiences are provided are also important. Teachers need sufficient opportunities to work in environments in which they have time and access to participate in support activities and professional interactions with colleagues along with time to reflect on their own pedagogy. The amount of time devoted to these professional development experiences are important for transference to occur into the science classrooms. These considerations concerning proper professional development are needed for inquiry-based instruction to become prevalent in science classrooms.

A fourth implication was that curriculum developers need to provide instructional materials that are well conceived, coherent, and current. Curriculum materials can directly affect what concepts teachers will teach, the methods of instruction teachers will use, and the learning experiences teachers will provide their students. Curriculum material needs to promote less emphasis on the purchase of textbooks based on didactic topics and more

emphasis on the adoption and implementation of curriculum aligned with the standards. Most importantly, a conceptual approach that includes all the examples of inquiry-based instructional strategies as recommended by the National Science Standards is needed. Standards-based materials are needed to provide opportunities for students to become involved with rich content and engage in inquiry-based learning experiences.

Considerable effort has gone into disseminating research relating to the affects of inquiry-based instruction on student achievement to gain support for science education reform. Teachers are central to the success of reform efforts. Teachers need to understand and support the national science education reforms and national and state science standards. Teacher preparation institutes need to train and prepare science teachers for effective implementation of inquiry-based instruction. School districts need to provide teacher professional development, supervision and support for continuous growth and positive self-efficacy. Curriculum developers need to provide instructional materials that are appropriate and current for teachers to implement. It is imperative that science teachers have the necessary knowledge, professional development, supervision and support, and curriculum

materials to make reform efforts for inquiry-based instruction a success.

#### Implications for Future Research

It is educationally sound to develop new methods and models of instruction and learning based on empirical evidence. Educators are the most important factors to getting new reform into the classrooms. There is clearly a need for continued research that documents the advantages that inquiry-based instruction has on student learning and achievement. Furthermore, continued research is needed to mitigate science teachers from reverting to more traditional means of instruction.

The research design used in this study suffered from two shortcomings that limit its actual usefulness. First, although the TIMSS 2007 study presents enormous bodies of data for analysis, this study is a secondary analysis, which poses all the cautions that are true of secondary analysis studies. Data collected from the teachers were limited by the questions asked, the directions for those questions, and the response selections provided. Second, this study relied on self-reported data to determine the orientation of science teachers, with respect to their preparedness and their instructional practices. The possibility of discrepancies in this study, such as

teachers' perceptions of their own instructional techniques or memory of the class in question, could result in distorted data. The findings of this study should be supplemented with or compared to other data sources. It is recommended that additional research on teaching practices focus on the video Study produced through TIMSS, which provided authentic classroom settings with a focus on teaching practices. This could provide a more accurate analysis of what actually occurred in the classrooms. In addition, researchers could develop their own instruments to determine the presence of inquiry-based instructional practices in the classroom as it was actually experienced by eighth-grade students. These possibilities would eliminate shortcomings that are inherent in questionnaires that require teachers to self-report information.

More studies are needed to investigate the instructional techniques science teachers are implementing in the science classrooms. Empirical evidence is necessary to help ensure proven methods and models of instruction are visible in classrooms. Many factors influence teacher practices. Continued educational research helps to determine how to get the best instructional practice into the classrooms.

## Summary

Several documents and studies claim American students lag behind international standards and continue underperforming in science (Martin, Mullis, Gonzalez, & Chrostowski, 2004; Parker and Gerber, 2000; Roth, Druker, Garnier, Lemmens, Chen, Kawanaka, Rasmussen, Trubacova, Warvi, Okamoto, Gonzales, Stigler, & Gallimore, 2006; Stigler & Hiebert, 1999). Science educators are working to improve science education. Science education researchers and National Research Council, stress the inclusion of inquiry-based science instruction into school science programs and curriculum. Inquiry-based instruction helps students achieve science understanding by combining scientific knowledge with reasoning and thinking skills (National Research Council, 2000). To implement inquiry-based instruction into science classrooms successfully, teachers need to feel prepared using inquiry-based approaches. Teachers will require knowledge of science content and pedagogy.

This study examined the relationship between teachers' preparedness to teach science content and their orientation of inquiry-base instructional practices to the science achievement of eighth grade science students in the United States as demonstrated on the TIMSS 2007 exam. Through

correlation analysis, the researcher found statistically significant positive relationships emerge between eighth grade science teachers' main area of study and their self-reported beliefs about their preparedness to teach that same content area. Another correlation analysis found a statistically significant positive relationship existed between teachers' self-reported use of inquiry-based instruction and preparedness to teach biology, chemistry and physics, respectively. There was a statistically significant negative relationship between teachers' self-reported use of inquiry-based instruction practices and preparedness to teach earth science. Another correlation analysis discovered a statistically significant positive relationship existed between physics preparedness and student science achievement. Teachers indicating physics as their main area of study also had a statistically significant positive relationship with having feelings of preparedness for both chemistry and earth science. According to this study, physics teachers indicated feelings of being prepared to teach all science subjects except biology and it was physics teachers who indicated a statistically significant positive relationship between physics preparedness and student science achievement. Finally, a correlation analysis found a statistically

significant positive relationship existed between science teachers' self-reported implementation of inquiry-based instructional practices and student achievement. The data finding in this study are consistent with other studies that correlate inquiry-based science instruction with an increase in student achievement.

The data findings support the conclusion that teachers who have feelings of preparedness to teach science content and implement more inquiry-based instruction and less didactic instruction produce high achieving science students. As science teachers obtain the appropriate knowledge in science content and pedagogy, science teachers will feel prepared and will implement inquiry-based instruction in science classrooms. The impact on teachers implementing inquiry-based instruction will become increasingly evident with student achievement.

Science educators continue to work to improve science education for all students. Inquiry-based instruction helps students achieve science understanding by combining scientific knowledge with reasoning and thinking skills (National Research Council, 2000). It is important that science educators continue to give priority to the implementation of inquiry-based learning opportunities.

## References

- Adams, P.E. & Krockover, G.H. (1997). Beginning science teacher cognition and its origins in the preservice secondary science teacher program. *Journal of Research in Science Teaching*, 34, 633-653.
- Allan, G., & Powell, N. (2007, December). Examining the Underlying Principles of Enquiry-Based Learning: Two Instances of where Learning Sessions Start and End. *International Journal of Learning*, 14(8), 157-165. Retrieved June 27, 2008, from Education Research Complete database.
- Allan, G., & Powell, N. (2007, December). Examining the Underlying Principles of Enquiry-Based Learning: Two Instances of where Learning Sessions Start and End. *International Journal of Learning*, 14(8), 157-165. Retrieved June 27, 2008, from Education Research Complete database.
- Alton-Lee, A. (2003). *Quality teaching for diverse students in schooling: Best evidence synthesis*. Wellington, NZ: New Zealand Ministry of Education.
- American Association for the Advancement of Science. (1990). *Science for All Americans*. New York: Oxford University Press.

- American Association for the Advancement of Science.  
(1993). *Benchmarks for Science Literacy*. New York:  
Oxford University Press. American Association for the  
Advancement of Science. (2001). *Designs for Science  
Literacy*. New York: Oxford University Press.
- Anderson, R.D., & Helms, J.V. (2001). The ideal of  
standards and the reality of schools: Needed  
research. *Journal of Research in Science Teaching*,  
38(1), 3-16.
- Aoki, J., Foster, A., & Ramsey, J. (2005, October).  
Inquiry perceptions held by responding Greater  
Houston-Area science supervisors. *The Texas Science  
Teacher*, 34(2), 17-22.
- Arenson, K.W. (2004, February 10). Study says U.S. should  
replace states' high school standards. *New York  
Times*.
- Ausubel, D.P. (2000). *The Acquisition and retention of  
Knowledge: A Cognitive View*. Dordrecht: Kluwer  
Academic Publishers.
- Barrow, L.H. (2006). A brief history of inquiry: From  
Dewey to standards. *Journal of Science Teacher  
Education*, 17, 265-278.

- Bolyard, J.J. & Moyer-Packenham, P.S. (2006). A review of the literature on mathematics and science teacher quality. *Peabody Journal of Education*, 83, 509-535.
- Bonnstetter, R.J. (1998). Inquiry: Learning from the past with an eye to the future. *Electronic Journal of Science Education*, 3(1), 130-136.
- Brooks, J., Brooks, M., & Association for Supervision and Curriculum Development, A. (1993, January 1). In *Search of Understanding: The Case for Constructivist Classrooms*. . (ERIC Document Reproduction Service No. ED366428) Retrieved July 31, 2008, from ERIC database.
- Buck, G.A, Latta, M.A.M., & Leslie-Pelecky, D.L. (2007). Learning how to make inquiry into electricity and magnetism discernible to middle level teachers. *Journal of Science Teacher Education*, 18, 377-397.
- Burrowes, P. (2003). A student-centered approach to teaching general biology that really works: Lord's constructivist model put to a test. *American Biology Teacher*, 65(7), 491-502.
- Bybee, R.W. (1993). *Reforming science education*. New York: Teachers College Press.
- Bybee, R.W. (2000). Teaching science as inquiry. In J. Minstrell & E.H. van Zee (Eds.), *Inquiring into Inquiry Learning and Teaching in Science* (pp. 20-46).

- Washington, D.C.: American Association for the Advancement of Science.
- Carlson, K.S. (2003). Constructivism: What it means for my own teaching. *Center for Development of Teaching and Learning Brief*, 6(1), 1-3.
- Chaney, B. (1995). *Student outcomes and the professional preparation of eighth-grade teachers in science and mathematics*. NSF/NELS:88 teacher transcript analysis (Reports-Research/Technical, 143). Arlington, VA: National Science Foundation.
- Chang, C.Y. & Mao, S.L. (1999). Comparison of Taiwan science students' outcomes with inquiry-group versus traditional instruction. *Journal of Educational Research*, 92(6), 340-346.
- Colburn, A. (2006). *What teacher educators need to know about inquiry-based instruction*. Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Akron, OH.
- Collette, A.T., & Chiappetta, E.L. (1994). *Science instruction in the middle and secondary schools* (3<sup>rd</sup> ed.). New York: Merrill.
- Constenson, K., & Lawson, A. (1986). Why isn't inquiry used in more classrooms? *The American Biology Teacher*, 48(3), 150-158.

- Crawford, B.A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching*, 37(9), 916-937.
- Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching*, 42(3), 337-357.
- Darling-Hammond, L. (2000). Teacher quality and student achievement: a review of state policy evidence. Education Policy Analysis Archives. *Journal of Science Teacher Education*, 8(1), 377-397.
- Dewey, J. (1910). Science as subject matter and as method. *Science*, 31(787) 121-127.
- Dewey, J. (1916). Methods in science teaching. *The Science Quarterly*, 1, 3-9.
- Dewey, J. (1938). *Experience and Education*. New York: Collier Books.
- Dewey, J. (1959). My Pedagogic creed. In *Dewey on Education* (p. 30.). New York: Bureau of Publications, Teachers College, Columbia University.
- Driver, R. (1989). The construction of scientific knowledge in school classrooms. In R. Miller (Ed.), *Doing science: Images of science in science education*. New York: Falmer Press.

- Ebert-May, D., Brewer, C., & Allred, S. (1997).  
 Innovation in large lectures- Teaching for active  
 learning. *Bioscience*, 47(9), 601-607.
- Eick, C.J & Reed, C.J. (2002). What makes an inquiry-  
 oriented science teacher? The influence of learning  
 histories on student teacher role identity and  
 practice. *Science Education*, 86(3), 401-416.
- Eisenhart, M.A, Finkel, E., & Marion, S.F. (1996).  
 Creating the condiotns for sicnetific literacy: A re-  
 examination. *American Educational Research Journal*,  
 33, 261-295.
- Escalada, L.T., & Zollman, D. A. (1997). An investigation  
 on the effects of using interactive digital video in a  
 physics classroom on student learning and attitudes.  
*Journal of Research in Science Teaching*, 34(5), 467-  
 489.
- Flick, L.B. (2000). Cognitive scaffolding that fosters  
 scientific inquiry in middle level science. *Journal  
 of Science Teacher Education*, 11(2), 109-129.
- Flick, L.B., Keys, C.W., Westbrook, S.L., Crawford, B.A., &  
 Cames, N.G. (1997, March 22). *Perspectives on Inquiry-  
 Oriented Teaching Practice: Conflict and  
 Clarification*. (ERIC Document Reproduction Service No.  
 ED407255) Retrieved July 30, 2009, from ERIC database.

- Freedman, M.P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching*, 34(5), 342-357.
- French, D. (2003). Addressing the middle grades gap. *The Term Paper*, 4, 4-6.
- Glass, G.V. (1976). Primary, secondary and meta-analysis of research. *Educational Researcher*, 5, 3-8.
- Goldhaber, D.D & Brewer, D.J. (1997). Evaluating the effect of teacher degree level on educational performance. In W.J. Fowler (Ed.), *Developments in school finance*, 1996 (pp. 197-210).
- Grigg, W.S., Lauko, M.A., and Brockway, D.M. (2006). *The Nation's Report Card: Science 2005* (NCES 2006-466). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
- Goldhaber, D.D & Brewer, D.J. (1998). When should we reward degrees for teachers? *Phi Delta Kappan*, 80(134), 136-138.
- Goldhaber, D.D & Brewer, D.J. (2000). Does teacher certification matter? High school teacher certification status and student achievement.

- Educational Evaluation and Policy Analysis*, 22(2), 129-146.
- Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth-and Eighth-Grade Students in an International Context* (NCES 2009-001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.
- Haefner, L.A., & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education*, 26(13), 1653-1674.
- Haney, J.J., Lumpe, A.T., Czerniak, C.M, & Egan, V. (2002). From beliefs to actions: The beliefs and actions of teachers implementing change. *Journal of Science Teacher Education*, 13(3), 171-187.
- Harms, N., & Kahl, S. (1980). *Project synthesis*. A final report submitted to the National Science Foundation. Boulder, CO: University of Colorado.

- Harms, N., & Yager, R.E. (Eds.). (1981). *What Research Says to the Science Teacher* (vol. 3). Washington, D.C.: National Science Teachers Association.
- Hawk, P.P., Coble, C.R., & Swanson, M. (1985). Certification: It does matter. *Journal of Teacher Education*, 36(3), 13-15.
- Hein, G. (2002). Director, Program Evaluation and Research Group, Lesley College, Cambridge, MA. In D. Llewellyn, *Inquire within: Implementing inquiry-based science standards*. Thousand Oaks, CA: Corwin.
- Helgeson, S., Blosser, P., & Howe, R. (1977). *The status of pre-college science, mathematics, and social studies education* (pp. 1955-1975). Columbus: Ohio State University, Center on Science and Mathematics Education.
- Henson, K.T. (1986). Inquiry learning: a new look. *Contemporary Education*, 57, 181-183.
- Hodson, D. (1999). Building a case for a sociocultural and inquiry-oriented view of science education. *Journal of Science Education and Technology*, 8(3), 241-249.
- Hurd, P.D., Bybee, R.W., Kahle, J.B., & Yager, R.E. (1980). Biology education in secondary schools of the

- United States. *The American Biology Teacher*, 42(7), 388-410.
- Hyman, H.H. (1972). *Secondary analysis of sample surveys: Principles, procedures, and potentialities*. New York: Wiley.
- Johnson, C.C., Kahle, J.B, & Fargo, J.D. (2006). Effective teaching results in increased science achievement for all students. *Science Education*, 91, 372-383.
- Joncas, M. (2008). TIMSS 2007 sample design. In Olson, J.F, Martin, M.O., & Mullis I.V. (Eds.). *TIMSS 2007 Technical Report*. (pp. 77-92). Chestnut Hill, MA: Boston College.
- Kahle, J., Meece, J., & Scantlebury, K. (2000). Urban African-American middle school science students: Does standards-based teaching make a difference. *Journal of Research in Science Teaching*, 37(9), 1019-1041.
- Keys, C.W., & Bryan, L.A. (2001). Co-Constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, 38(6), 631-645.
- Keys, C.W., & Kennedy, V. (1999). Understanding inquiry science teaching in context: A case study of an

- elementary teacher. *Journal of Research in Science Teaching*, 38(6), 631-645.
- Kluger-Bell, B. (1999). *Recognizing inquiry: Comparing three hands-on teaching techniques*. In National Science Foundation (Ed.), *Inquiry thoughts, views, and strategies for the K-5 classroom* (pp.39-50). Arlington, VA: National Science Foundation.
- Mao, S.L., & Chang, C.Y. (1997). *The effects of instructional strategies on ninth-grade students' skills of data interpretation and concept formation*. Unpublished report, National Science Council No. NSC86-2511-S-003-024.
- Martin, M.O, Mullis, I., Gonzalez, E.J., Chrostowski, S.J. (2004). *TIMSS 2003 International Science Report: Findings from IEA's trends in international mathematics and science study at the fourth and eighth grades*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.
- Martin-Hauser, L. (2002). Defining inquiry. *The Science Teacher*, 69(2), 34-37.
- Mattern, N., & Schau, C. (2002). Gender differences in science attitude-achievement relationships over time among white middle-school students. *Journal of Research in Science Teaching*, 39(4), 324-340.

- Mayer, D.P., Mullens, J.E, & Moore, M.T. (2000).  
*Monitoring school quality: An indicators report*, NCES  
2001-030, Washington, DC: National Center for  
Education Statistics.
- McCreary, C.L., Golde, M.F., and Koeske. (2006). Peer  
instruction in the general chemistry laboratory:  
Assessment of student learning. *Journal of Chemical  
Education*, 83(5), 804-810.
- Miller, J.D. (1982). Secondary analysis and science  
education research. *Journal of Researching Science  
Teaching*, 19(9), 719-725.
- Monk, D.H. (1994). Subject area preparation of secondary  
mathematics and science teachers and student  
achievement. *Journal of Teacher Education*, 49, 165-  
176.
- Morell, P.D., & Lederman, N.G. (1998). Students'  
attitudes toward school and classroom science: Are  
they independent phenomena? *School Science and  
Mathematics*, 98(2), 76-83.
- Mullis, I.V.S., Martin, M.O., & Foy, P. (2005). *IEA's  
TIMSS 2003 International Report on Achievement in the  
Mathematics Cognitive Domains: Findings From a  
Developmental Project*. Chestnut Hill, MA: Boston  
College.

- Mullis, I.V.S., Martin, M.O, Rudock, G.J., O'Sullivan, C.Y., Arora, A., and Erberber, E. (2005). *TIMSS 2007 Assessment Frameworks*. Chestnut Hill, MA: Boston College.
- National Research Council. (1996a). *From Analysis to Action, undergraduate education in science, mathematics, engineering, and technology, report of a convocation*. Washington, DC: National Academy Press.
- National Science Foundation, Advisory Committee for the National Science Foundation.
- National Research Council. (1996b). *National Science Education Standards*. Washington, DC: National Academy Press.
- National Research Council. (2000). *National Science Education Standards*. Washington, DC: National Academy Press.
- Newman, W.J., Abell, S.K., Hubbard, P.D., McDonald, J., Otaala, J., & Martini, M. (2004). Dilemmas of teaching inquiry in elementary science methods. *Journal of Science Teacher Education*, 15(4), 257-279.
- Okebukola, P.A. (1987). Students' performance in practical chemistry: A study of some related factors. *Journal of Research in Science Teaching*, 24(2), 119-126.

- Oliver-Hoyo, M., Allen, D. and Anderson, M. (2004).  
Inquiry-guided instruction practical issues of  
implementation. *Journal of college Science Teaching*,  
33(6), 20-24.
- Oliver-Hoyo, M. & Allen, D. (2005). Attitudinal effects  
of a student-centered active learning environment.  
*Journal of Chemical Education*, 82(6), 944-949.
- Olson, J.F., Martin, M.O., & Mullis, I.V.S. (Eds.).  
(2008). *TIMSS 2007 Technical Report*. Chestnut Hill,  
MA: Boston College.
- Parker, V. & Gerber, B. (2000). Effects of a science  
intervention program on middle-grade student  
achievement and attitudes. *School Science and  
Mathematics*, 100(5), 236-242.
- Pederson, J.E., & Totten, S. (2001). Beliefs of science  
teachers toward the teaching of  
science/technological/social issues: Are we  
addressing National Standards? *Bulletin of Science,  
Technology and Society*, 21(5), 376-393.
- Plourde, L. (2002). The influence of student teaching on  
preservice elementary teachers' science self-efficacy  
and outcome expectancy beliefs. *Journal of  
Instructional Psychology*, 29, 245-253.

- Rice, J.K. (2003). *Teacher quality: Understanding the effectiveness of teacher attributes*. Washington, DC: Economic Policy Institute.
- Roth, K.J., Druker, S.L., Garnier, H.E., Lemmens, M., Chen, C., Kawanaka, T., Rasmussen, D., Trubacova, S., Warvi, D., Okamoto, Y., Gonzales, P., Stigler, J., and Gallimore, R. Study (2006). *Teaching Science in Five countries: Results From the TIMSS 1999 Video Study* (NCES 2006-011). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
- Rutherford, F.J. (1964). The role of inquiry in science teaching; *Journal of Research in Science Teaching*, 2, 80-84.
- Rutherford, F.J., & Ahlgren, A. (1989). *Science for all Americans: A Project 2061 report*. Washington, DC: American Association for the Advancement of Science.
- Saderholm, J.C., & Tretter, T.R. (2008). Identification of the most critical content knowledge base for middle school science teachers. *Journal of Science Teacher Education*, (19), 269-283.
- Schmidt, W.H., McKnight, C.C., & Raizen, S. A. (1996). *A splintered vision: An Investigation of U.S. Science*

- and Mathematics Education*. Boston, MA: Kluwer Academic Publishers.
- Schwab, J.J. (1958). The teaching of science as inquiry. *Bulletin of the Atomic Scientists*, 14(9), 374-379.
- Schwab, J.J. (1960). Enquiry, the science teacher, and the educator. *The Science Teacher*, 27, 6-11.
- Schwab, J.J. (1962). The teaching of science as enquiry. In J.J. Schwab & P.F. Brandwein (Eds.), *The teaching of science* (pp. 1-103). Cambridge, MA: Harvard University Press.
- Schwab, J.J. (1966). *The teaching of science*. Cambridge, MA: Harvard University Press.
- Settlage, J. (2007). Demythologizing science teacher education: Conquering the false ideal of open inquiry. *Journal of Science Teacher Education*, 18, 461-467.
- Seymour, E. (2002). Tracking the processes of change in U.S. undergraduate education in science, mathematics, engineering, and technology. *Science Education*, 85(6), 79-105.
- Shymansky, J., Hedges, L., & Woodworth, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance. *Journal of Research in Science Teaching*, 27(2), 127-144.

- Shymansky, J.A., Kyle, W.C. & Alport, J.M. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching*, 20(5), 387-404.
- Smerdon, B., Burkam, D., & Lee, V. (1999). Access to Constructivist and Didactic Teaching: Who Gets It? Where Is It Practiced?. *Teachers College Record*, 101(1), 5-34.
- Songer, N.B., Lee, H., & McDonald, S. (2003). Research towards an expanded understanding of inquiry science beyond one idealized standard. *Science Education*, 87(4), 490-516.
- Stake, R., & Easley, J. (1978). *Case studies in science education*. Urbana: University of Illinois, Center for Institutional Research and Curriculum Evaluation.
- Stigler, J.W., & Hiebert, J. (1999). *The teaching gap*. New York: The Free Press.
- Straits, W., & Wilke, R. (2003). Preparing for the science TAKS: Inquiry-based activities for fostering an understanding of the nature of science. *The Texas Science Teacher*, 32(2), 32-34.
- Straits, W., & Wilke, R. (2007). How constructivist are we? Representations of Transmission and Participatory models of instruction in the journal of

- college science teaching. *Journal of College Science Teaching*, 36(7), 58-61.
- Sutton, J., & Krueger, A. (Eds.). (2001). *EDThoughts: What we know about science teaching and learning*. Aurora, CO: Mid-continent Research for Education and Learning. (Eric Document Reproduction Service No. ED465535).
- Svinicki, M.D. (1998). A theoretical foundation for discovery learning. *Advances in Physiology Education*, 20(1), 4-7.
- Tamir, P. & Glassman, S. (1971). A practical examination for BSCS students: a progress report. *Journal of Research in Science Teaching*, 8, 307-315.
- Tamir, P. & Stavy, R., & Ratner, N. (1998). Teaching science by inquiry: Assessment and learning. *Journal of Biological Education*, 33(1), 27-32.
- Tobin, K. & Jakubowski, E. (1990, April). *Cognitive process and teacher change*. Paper presented at the annual meeting of the American Education Research Association, Boston.
- Unal, G. & Akpınar, E. (2006). To what extent science teachers are constructivist in their classrooms. *Journal of Baltic Science Education*, 2(10), 40-50.

- Valverde, G.A., & Schmidt, W.H. (2000). Greater expectations: Learning from other nations in the quest for 'world-class standards' in US school mathematics and science. *Journal of Curriculum Studies, 32*(5), 651-687.
- Von Secker, C. (2002). Effects of Inquiry-Based Teacher Practices on Science Excellence and Equity. *Journal of Educational Research, 95*(3), 151.
- Wee, B., Shepardson, D., Fast, J., & Harbor, J. (2007). Teaching and learning about inquiry: Insights and challenges in professional development. *Journal of Science Teacher Education, 18*, 63-89.
- Weiss, I. (1978). *Report of the 1977 national survey of science, mathematics and social studies education*. Washington, DC: U.S. Government Printing Office.
- Welch, W., Klopfer, L., Aikenhead, G., & Robinson, J. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education, 65*, 33-50.
- Wesstat. (2007). *WesVar 4.3 User's Guide*. Rockville, MD: Westat, Inc.
- Wilke, R.R. & Straits, W.J. (2005). Practical advice for teaching inquiry-based science process skills in the

- biological sciences. *The American Biology Teacher*, 67(9), 534-540.
- Wilke, R., & Straits, W. (2006). Developing Students' Process Skills in Today's Science Classroom. *Texas Science Teacher*, 35(1), 11-16.
- Williams, T., Ferraro, D., Roey, S., Brenwald, S., Kastberg, D., Jocelyn, L. et al. (2009). *TIMSS 2007 U.S. Technical Report and User Guide* (NCES 2009-012). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.
- Wilson, S.M., Floden, R.E. (2003). *Creating effective teachers: Concise answers for hard questions*. An addendum to the report "Teachers preparation research: Current knowledge, gaps, and recommendations." Education Commission of the States. (ERIC Document Reproduction Service No. ED 476366).
- Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice?. *Science Education*, 87(1), 112-143.
- Windschitl, M. (2004). Folk theories of "inquiry": How preservice teachers reproduce the discourse and practices of an atheoretical scientific method.

*Journal of Research in Science Teaching*, 41(5), 481-512.

## Appendix A

### Description of TIMSS 2007 Science Cognitive Domains

Cognitive Domain	Description
Knowing	<p><i>Knowing</i> addresses the facts, information, concepts, tools, and procedures that students need to know to function scientifically. The key skills of this cognitive domain include making or identifying accurate statements about science facts, relationships, processes, and concepts; identifying the characteristics or properties of specific organisms, materials, and processes; providing or identifying definitions of scientific terms; recognizing and using scientific vocabulary, symbols, abbreviations, units, and scales in relevant contexts; describing organisms, physical materials, and science processes that demonstrate knowledge of properties, structure, function, and relationships; supporting or clarifying statements of facts or concepts with appropriate examples; identifying or providing specific examples to illustrate knowledge of general concepts; and demonstrating knowledge of the use of scientific apparatus, tools, equipment, procedures, measurement devices, and scales.</p>
Applying	<p><i>Applying</i> focuses on students' ability to apply knowledge and conceptual understanding to solve problems or answer questions. The key skills of this cognitive domain include identifying or describing similarities and differences between groups of organisms, materials, or processes; distinguishing, classifying, or ordering individual objects, materials, organisms, and processes based on given characteristics and properties; using a diagram or model to demonstrate understanding of a science concept, structure, relationship, process, or biological or physical system or cycle; relating knowledge of an underlying biological or physical concept to an observed or inferred property, behavior, or use of objects, organisms, or materials; interpreting relevant textual, tabular, or graphical information in light of a science concept or principle; identifying or using a science relationship, equation, or formula to find a quantitative or qualitative solution involving the direct application or demonstration of a concept; providing or identifying an explanation for an observation or natural phenomena, demonstrating understanding of the underlying science concept, principle, law, or theory.</p>

Reasoning	<p><i>Reasoning</i> goes beyond the cognitive processes involved in solving routine problems to include more complex tasks. The key skills of this cognitive domain include analyzing problems to determine the relevant relationships, concepts, and problem-solving steps; developing and explaining problem-solving strategies; providing solutions to problems that require consideration of a number of different factors or related concepts; making associations or connections between concepts in different areas of science; demonstrating understanding of unified concepts and themes across the domains of science; integrating mathematical concepts or procedures in the solutions to science problems; combining knowledge of science concepts with information from experience or observation to formulate questions that can be answered by investigation; formulating hypotheses as testable assumptions using knowledge from observation or analysis of scientific information and conceptual understanding; making predictions about the effects of changes in biological or physical conditions in light of evidence and scientific understanding; designing or planning investigations appropriate for answering scientific questions or testing hypotheses; detecting patterns in data; describing or summarizing data trends; interpolating or extrapolating from data or given information; making valid inferences based on evidence; drawing appropriate conclusions; demonstrating understanding of cause and effect; making general conclusions that go beyond the experimental or given conditions; applying conclusions to new situations; determining general formulas for expressing physical relationships; evaluating the impact of science and technology on biological and physical systems; evaluating alternative explanations and problem-solving strategies; evaluating the validity of conclusions through examination of the available evidence; and constructing arguments to support the reasonableness of solutions to problems.</p>
-----------	---

NOTE: The descriptions of the cognitive domains are the same for grades four and eight.  
(Gonzales et al., 2008, p. 35)

Appendix B

**Identification Label** \_\_\_\_\_

Teacher Name: \_\_\_\_\_

Class Name: \_\_\_\_\_

Teacher ID: \_\_\_\_\_ Teacher Link # \_\_\_\_\_

Trends in International Mathematics and Science Study

**TIMSS 2007**



**Teacher Questionnaire**

**SCIENCE**  
**<Grade 8>**

**<TIMSS National Research Center Name>**  
<Address>



International Association for the Evaluation  
of Educational Achievement  
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# General Directions

Your school has agreed to participate in TIMSS 2007, a large international study of student learning in mathematics and science in more than 60 countries around the world. Sponsored by the International Association for the Evaluation of Educational Achievement (IEA), TIMSS (for Trends in International Mathematics and Science Study) is measuring trends in student achievement and studying differences in national education systems in order to help improve the teaching and learning of mathematics and science worldwide.

As part of the study, students in a nationwide sample of <eighth-grade> classes in <country> will complete the TIMSS mathematics and science tests. This questionnaire is addressed to teachers who teach science to these students, and seeks information about teachers' academic and professional background, instructional practices, and attitudes toward teaching science. As a teacher of science to students in one of these sampled classes, your responses to these questions are very important in helping to describe science education in <country>.

Some of the questions in this questionnaire refer specifically to students in the "TIMSS class." This is the class that is identified on the cover of this questionnaire, and that will be tested as part of TIMSS 2007 in your school. If you teach science to some but not all of the students in the TIMSS class, please think of teaching the science class these students are in when answering these class-specific questions. It is important that you answer each question carefully so that the information that you provide reflects your situation as accurately as possible.

Please identify a time and place where you will be able to complete this questionnaire without being interrupted. This should require no more than 45 minutes. To make it as easy as possible for you to respond, most questions may be answered simply by checking or filling in the appropriate circle.

Once you have completed the questionnaire, place it in the return envelope provided and return it to: <Country Specific Information>

Thank you very much for the time and effort you have put into responding to this questionnaire.

## Background Information

### 1 **How old are you?**

Fill in **one** circle only

- Under 25 -----○  
25–29 -----○  
30–39 -----○  
40–49 -----○  
50–59 -----○  
60 or older -----○

### 2 **Are you female or male?**

Fill in **one** circle only

- Female -----○  
Male -----○

### 3 **By the end of this school year, how many years will you have been teaching altogether?**

\_\_\_\_\_  
*Number of years you have taught*

## Preparation to Teach

### 4 **What is the highest level of formal education you have completed?**

Fill in **one** circle only

- Did not complete <ISCED 3> -----○  
Finished <ISCED 3> -----○  
Finished <ISCED 4> -----○  
Finished <ISCED 5B> -----○  
Finished <ISCED 5A, first degree> -----○  
Finished <ISCED 5A, second degree> or higher -----○

### 5 **During your <post-secondary> education, what was your major or main area(s) of study?**

Fill in **one** circle for each row

- |                                   | Yes | No |
|-----------------------------------|-----|----|
| a) Biology -----○                 | ○   | ○  |
| b) Physics -----○                 | ○   | ○  |
| c) Chemistry -----○               | ○   | ○  |
| d) <Earth Science> -----○         | ○   | ○  |
| e) Education - Science -----○     | ○   | ○  |
| f) Mathematics -----○             | ○   | ○  |
| g) Education - Mathematics -----○ | ○   | ○  |
| h) Education - General -----○     | ○   | ○  |
| i) Other -----○                   | ○   | ○  |

### 6 **Do you have a teaching license or certificate?**

Yes      No  
|  
|

Fill in **one** circle only -----○

## Preparation to Teach (Continued)

7

How well prepared do you feel you are to teach the following topics?

Fill in **one** circle for each row

	Not well prepared	Somewhat prepared	Very well prepared	Not applicable
--	-------------------	-------------------	--------------------	----------------

### A. Biology

- |   |                       |                       |                       |                       |
|---|-----------------------|-----------------------|-----------------------|-----------------------|
| a) Major organs and organ systems in humans and other organisms (structure/function, life processes that maintain stable bodily conditions) -----       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| b) Cells and their functions, including respiration and photosynthesis as cellular processes ---  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| c) Reproduction (sexual and asexual) and heredity (passing on of traits, inherited versus acquired/learned characteristics) -----                       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| d) Role of variation and adaptation in survival/extinction of species in a changing environment -----   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| e) Interaction of living organisms and the physical environment in an ecosystem (energy flow, food webs, effect of changes, cycling of materials) ----- | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| f) Trends in human population and its effects on the environment -----  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| g) Impact of natural hazards on humans, wildlife, and the environment -----   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### B. Chemistry

- |  |                       |                       |                       |                       |
|--|-----------------------|-----------------------|-----------------------|-----------------------|
| a) Classification and composition of matter (properties of elements, compounds, mixtures)---   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| b) Particulate structure of matter (molecules, atoms, protons, neutrons, and electrons)-----   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| c) Solutions (solvent, solute, concentration/dilution, effect of temperature on solubility)-----   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| d) Properties and uses of common acids and bases -----   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| e) Chemical change (transformation of reactants, evidence of chemical change, conservation of matter, common oxidation reactions - combustion and rusting) ----- | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### C. Physics

- |  |                       |                       |                       |                       |
|--|-----------------------|-----------------------|-----------------------|-----------------------|
| a) Physical states and changes in matter (explanations of properties in terms of movement/distance between particles; phase change, thermal expansion and changes in volume and/or pressure) -----                           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| b) Energy forms, transformations, heat, and temperature -----  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| c) Basic properties/behaviors of light (reflection, refraction, light and color, simple ray diagrams) and sound (transmission through media, loudness, pitch, amplitude, frequency, relative speed of light and sound) ----- | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| d) Electric circuits (flow of current; types of circuits - parallel/series; current/voltage relationship)-----   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| e) Properties of permanent magnets and electromagnets -----  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| f) Forces and motion (types of forces, basic description of motion, use of distance/time graphs, effects of density and pressure) -----  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

**7 Continued**

How well prepared do you feel you are to teach the following topics?

Fill in **one** circle for each row

	Not well prepared	Somewhat prepared	Very well prepared	Not applicable
--	-------------------	-------------------	--------------------	----------------

**D. Earth Science**

- a) Earth's structure and physical features (Earth's crust, mantle and core; use of topographic maps) ----- ○ -- ○ -- ○ -- ○
- b) Earth's processes, cycles and history (rock cycle; water cycle; weather patterns; major geological events; formation of fossils and fossil fuels) ----- ○ -- ○ -- ○ -- ○
- c) Environmental concerns (e.g., pollution, global warming, acid rain) ----- ○ -- ○ -- ○ -- ○
- d) Use and conservation of Earth's natural resources (renewable/non-renewable resources, human use of land/soil and water resources) ----- ○ -- ○ -- ○ -- ○
- e) Earth in the solar system and the universe (phenomena on Earth - day/night, tides, phases of moon, eclipses, seasons; physical features of Earth compared to other bodies; the Sun as a star) ----- ○ -- ○ -- ○ -- ○

**8** How often do you have the following types of interactions with other teachers?

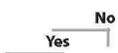
Fill in **one** circle for each row



- a) Discussions about how to teach a particular concept -- ○ -- ○ -- ○ -- ○
- b) Working on preparing instructional materials ----- ○ -- ○ -- ○ -- ○
- c) Visits to another teacher's classroom to observe his/her teaching ----- ○ -- ○ -- ○ -- ○
- d) Informal observations of **my** classroom by another teacher ----- ○ -- ○ -- ○ -- ○

**9** In the past two years, have you participated in professional development in any of the following?

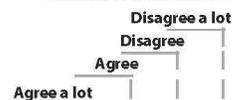
Fill in **one** circle for each row



- a) Science content ----- ○ -- ○
- b) Science pedagogy/Instruction ----- ○ -- ○
- c) Science curriculum ----- ○ -- ○
- d) Integrating information technology into science ----- ○ -- ○
- e) Improving students' critical thinking or inquiry skills ----- ○ -- ○
- f) Science assessment ----- ○ -- ○

**10** Thinking about your current school, indicate the extent to which you agree or disagree with each of the following statements.

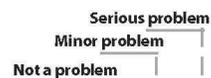
Fill in **one** circle for each row



- a) This school is located in a safe neighborhood ----- ○ -- ○ -- ○ -- ○
- b) I feel safe at this school ----- ○ -- ○ -- ○ -- ○
- c) This school's security policies and practices are sufficient - ○ -- ○ -- ○ -- ○

**11** In your current school, how severe is each problem?

Fill in **one** circle for each row

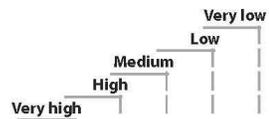


- a) The school building needs significant repair ----- ○ -- ○ -- ○ -- ○
- b) Classrooms are overcrowded ----- ○ -- ○ -- ○ -- ○
- c) Teachers do not have adequate workspace outside their classroom ----- ○ -- ○ -- ○ -- ○
- d) Materials are not available to conduct science experiments or investigations ----- ○ -- ○ -- ○ -- ○

12

How would you characterize each of the following within your school?

Fill in **one** circle for each row



- a) Teachers' job satisfaction -----  --  --  --  --
- b) Teachers' understanding of the school's curricular goals -----  --  --  --  --
- c) Teachers' degree of success in implementing the school's curriculum  --  --  --  --
- d) Teachers' expectations for student achievement -----  --  --  --  --
- e) Parental support for student achievement -  --  --  --  --
- f) Parental involvement in school activities ---  --  --  --  --
- g) Students' regard for school property -----  --  --  --  --
- h) Students' desire to do well in school -----  --  --  --  --



## The TIMSS Class

The remaining questions refer to the <TIMSS class / class with the TIMSS students>. Remember, "the TIMSS class" is the class which is identified on the cover of this questionnaire, and which will be tested as part of TIMSS 2007 in your school.

**13** \_\_\_\_\_

How many students are in the <TIMSS class/  
class with the TIMSS students>?

\_\_\_\_\_ *Write in the number of students*

**14** \_\_\_\_\_

How many minutes per week do you teach  
science to the <TIMSS class>?

\_\_\_\_\_ *Write in the number of minutes per week*

**15** \_\_\_\_\_

**A. Do you use a textbook(s) in teaching science to  
the <TIMSS class>?**

Yes  No

Fill in **one** circle only-----○-----○

If **No**, please go to question **16** 

**B. How do you use a textbook(s) in teaching  
science to the <TIMSS class>?**

Fill in **one** circle only

As the primary basis for my lessons-----○

As a supplementary resource-----○

**16** \_\_\_\_\_

In a typical week of science lessons for the  
<TIMSS class>, what percentage of time do  
students spend on each of the following  
activities?

\_\_\_\_\_ *Write in the percent*  
The total should add to 100%

- a) Reviewing homework -----○-----%
- b) Listening to lecture-style presentations -----○-----%
- c) Working problems with your guidance -----○-----%
- d) Working problems on their own without your guidance -----○-----%
- e) Listening to you re-teach and clarify content/procedures -----○-----%
- f) Taking tests or quizzes-----○-----%
- g) Participating in classroom management tasks not related to the lesson's content/purpose (e.g., interruptions and keeping order)-----○-----%
- h) Other student activities -----○-----%

**Total** -----○----- 100%

## Teaching Science to the TIMSS Class

17

In teaching science to the students in the <TIMSS class>, how often do you usually ask them to do the following?

Fill in **one** circle for each row

Never  
Some lessons  
About half the lessons  
Every or almost every lesson

- a) Observe natural phenomena and describe what they see -----  --  --  --  --
- b) Watch me demonstrate an experiment or investigation -----  --  --  --  --
- c) Design or plan experiments or investigations -----  --  --  --  --
- d) Conduct experiments or investigations -----  --  --  --  --
- e) Work together in small groups on experiments or investigations -----  --  --  --  --
- f) Read their textbooks or other resource materials ---  --  --  --  --
- g) Have students memorize facts and principles -----  --  --  --  --
- h) Use scientific formulae and laws to solve routine problems -----  --  --  --  --
- i) Give explanations about something they are studying -----  --  --  --  --
- j) Relate what they are learning in science to their daily lives -----  --  --  --  --

18

In your view, to what extent do the following limit how you teach the <TIMSS class>?

Fill in **one** circle for each row

Not applicable  
Not at all  
A little  
Some  
A lot

### Students

- a) Students with different academic abilities ---  --  --  --  --
- b) Students who come from a wide range of backgrounds (e.g., economic, language) -  --  --  --  --
- c) Students with special needs (e.g., hearing, vision, speech impairment, physical disabilities, mental or emotional/psychological impairment) -----  --  --  --  --
- d) Uninterested students  --  --  --  --
- e) Disruptive students --  --  --  --  --

### Resources

- f) Shortage of computer hardware --  --  --  --  --
- g) Shortage of computer software ---  --  --  --  --
- h) Shortage of support for using computers --  --  --  --  --
- i) Shortage of textbooks for student use -----  --  --  --  --
- j) Shortage of other instructional equipment for students' use -----  --  --  --  --
- k) Shortage of equipment for your use in demonstrations and other exercises --  --  --  --  --
- l) Inadequate physical facilities -----  --  --  --  --
- m) High student/teacher ratio -----  --  --  --  --

19

**By the end of this school year, approximately what percentage of teaching time will you have spent during this school year on each of the following science content areas for the <TIMSS class>?**

*Write in the percent  
The total should add to 100%*

- a) Biology (e.g., structure/function; life processes, reproduction/heredity, natural selection; ecosystems, human health)----- %
  - b) Chemistry (e.g., classification, composition and properties of matter; chemical change) ----- %
  - c) Physics (e.g., physical states/ changes in matter; energy; light; sound; electricity and magnetism; forces and motion) ----- %
  - d) Earth science (e.g., Earth's structure, processes, and resources; the solar system and universe) ----- %
  - e) Other, please specify:  
----- %
- Total** ----- 100%

The following list includes the main topics addressed by the TIMSS science test. Choose the response that best describes when students in the <TIMSS class> have been taught each topic. If a topic was taught half this year but not yet completed, please choose "Mostly taught this year." If a topic is not in the curriculum, please choose "Not yet taught or just introduced."

Fill in **one** circle for each row

	Not yet taught or just introduced		
	Mostly taught this year		
	Mostly taught before this year		

**A. Biology**

- a) Classification of organisms on the basis of a variety of physical and behavioral characteristics .....  --  --
- b) Major organ systems in humans and other organisms .....  --  --
- c) How the systems function to maintain stable bodily conditions .....  --  --
- d) Cell structures and functions .....  --  --
- e) Photosynthesis and respiration (including substances used and produced) as processes of cells and organisms .....  --  --
- f) Life cycles of organisms, including humans, plants, birds, insects .....  --  --
- g) Reproduction (sexual and asexual), and heredity (passing on of traits, inherited versus acquired/learned characteristics).....  --  --
- h) Role of variation and adaptation in survival/extinction of species in a changing environment .....  --  --
- i) Interaction of living organisms in an ecosystem (energy flow, food chains and food webs, food pyramids, and the effects of change upon the system)- .....  --  --
- j) Cycling of materials in nature (water, carbon/oxygen cycle, decomposition of organisms) .....  --  --
- k) Trends in human population and its effects on the environment .....  --  --
- l) Impact of natural hazards on humans, wildlife, and the environment .....  --  --
- m) Causes of common infectious diseases, methods of infection/transmission, prevention, and the body's natural resistance and healing capabilities .....  --  --
- n) Preventive medicine methods (diet, hygiene, exercise, and lifestyle) .....  --  --



**20 Continued**

The following list includes the main topics addressed by the TIMSS science test. Choose the response that best describes when students in the <TIMSS class> have been taught each topic. If a topic was taught half this year but not yet completed, please choose "Mostly taught this year." If a topic is not in the curriculum, please choose "Not yet taught or just introduced."

Fill in **one** circle for each row

	Not yet taught or just introduced	Mostly taught this year	Mostly taught before this year

**B. Chemistry**

- |  |   |    |   |    |   |
|--|---|----|---|----|---|
| a) Classification and composition of matter (physical and chemical properties, pure substances and mixtures, separation techniques) .....                  | ○ | -- | ○ | -- | ○ |
| b) Particulate structure of matter (molecules, atoms, protons, neutrons, and electrons) .....  | ○ | -- | ○ | -- | ○ |
| c) Solutions (solvents, solutes, effect of temperature on solubility) .....  | ○ | -- | ○ | -- | ○ |
| d) Properties and uses of water (composition, melting/boiling points, changes in density/volume) .....   | ○ | -- | ○ | -- | ○ |
| e) Properties and uses of common acids and bases .....   | ○ | -- | ○ | -- | ○ |
| f) Chemical change (transformation of reactants, evidence of chemical change, conservation of matter) .....  | ○ | -- | ○ | -- | ○ |
| g) Common oxidation reactions (combustion, rusting), the need for oxygen and the relative tendency of familiar substances to undergo these reactions ..... | ○ | -- | ○ | -- | ○ |
| h) Classification of familiar chemical transformations as releasing or absorbing heat/energy .....   | ○ | -- | ○ | -- | ○ |

**20 Continued**

The following list includes the main topics addressed by the TIMSS science test. Choose the response that best describes when students in the <TIMSS class> have been taught each topic. If a topic was taught half this year but not yet completed, please choose "Mostly taught this year." If a topic is not in the curriculum, please choose "Not yet taught or just introduced."

Fill in **one** circle for each row

	Not yet taught or just introduced	Mostly taught this year	Mostly taught before this year
--	-----------------------------------	-------------------------	--------------------------------

**C. Physics**

- a) Physical states and changes in matter (explanations of properties including volume, shape, density, and compressibility in terms of movement/distance between particles, conservation of mass during physical changes) -----  --  --
- b) Processes of melting, freezing, evaporation, and condensation (phase change; melting/boiling points; effects of pressure and purity of substances)-----  --  --
- c) Energy forms, transformations, heat and temperature, including heat transfer -----  --  --
- d) Temperature changes related to changes in volume and/or pressure and to changes in movement or speed of particles -----  --  --
- e) Basic properties/behavior of light (reflection, refraction, light and color, simple ray diagrams) ----  --  --
- f) Properties of sound (transmission through media, ways of describing sound (loudness, pitch, amplitude, frequency), relative speed) -----  --  --
- g) Electric circuits (flow of current, types of circuits – parallel/series) and relationship between voltage and current -----  --  --
- h) Properties of permanent magnets and electromagnets -----  --  --
- i) Forces and motion (types of forces, basic description of motion), use of distance/time graphs -----  --  --
- j) Effects of density and pressure -----  --  --



**20 Continued**

The following list includes the main topics addressed by the TIMSS science test. Choose the response that best describes when students in the <TIMSS class> have been taught each topic. If a topic was taught half this year but not yet completed, please choose "Mostly taught this year." If a topic is not in the curriculum, please choose "Not yet taught or just introduced."

Fill in **one** circle for each row

	Not yet taught or just introduced		
	Mostly taught this year		
	Mostly taught before this year		

**D. Earth Science**

- a) Earth's structure and physical features  
(Earth's crust, mantle, and core; topographic maps) ----- ○ -- ○ -- ○
- b) The physical state, movement, composition, and relative distribution of water on Earth ----- ○ -- ○ -- ○
- c) Earth's atmosphere and the relative abundance of its main components ----- ○ -- ○ -- ○
- d) Earth's water cycle (steps, role of sun's energy, circulation/renewal of fresh water) ----- ○ -- ○ -- ○
- e) Processes in the rock cycle and the formation of igneous, metamorphic,  
and sedimentary rock ----- ○ -- ○ -- ○
- f) Weather data/maps and changes in weather patterns  
(e.g., seasonal changes, effects of latitude, altitude, and geography) ----- ○ -- ○ -- ○
- g) Geological processes occurring over millions of years  
(e.g., erosion, mountain building, plate movement) ----- ○ -- ○ -- ○
- h) Formation of fossils and fossil fuels ----- ○ -- ○ -- ○
- i) Environmental concerns (e.g., pollution, global warming, acid rain) ----- ○ -- ○ -- ○
- j) Earth's resources (renewable/nonrenewable, conservation, waste management) ----- ○ -- ○ -- ○
- k) Relationship of land management (e.g., pest control) to human use (e.g., farming) ----- ○ -- ○ -- ○
- l) Supply and demand of fresh water resources ----- ○ -- ○ -- ○
- m) Explanation of phenomena on Earth based on position/movement of bodies in the  
solar system and universe (e.g., day/night, tides, year, phases of the moon,  
eclipses, seasons, appearance of sun, moon, planets, and constellations) ----- ○ -- ○ -- ○
- n) Physical features of Earth compared with the moon and other planets  
(e.g., atmosphere, temperature, water, distance from sun, period of revolution/rotation,  
ability to support life) ----- ○ -- ○ -- ○

## Computers in the TIMSS Class

21 **\_\_\_\_\_**

A. Do students in the <TIMSS class> have computer(s) available to use during their science lessons?

Yes  No   
 Fill in **one** circle only -----○-----○

If **No**, please go to question 23 

B. Do any of the computer(s) have access to the Internet?

Yes  No   
 Fill in **one** circle only -----○-----○

22 **\_\_\_\_\_**

In teaching science to the <TIMSS class>, how often do you have students use a computer for the following activities?

Fill in **one** circle for each row

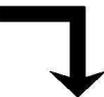
- |  | Every or almost every lesson | About half the lessons | Some lessons          | Never                 |
|--|------------------------------|------------------------|-----------------------|-----------------------|
| a) Do scientific procedures or experiments -----○--○--○--○     | <input type="radio"/>        | <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> |
| b) Study natural phenomena through simulations -----○--○--○--○ | <input type="radio"/>        | <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> |
| c) Practice skills and procedures -----○--○--○--○              | <input type="radio"/>        | <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> |
| d) Look up ideas and information -----○--○--○--○               | <input type="radio"/>        | <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> |
| e) Process and analyze data -----○--○--○--○                    | <input type="radio"/>        | <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> |



## Homework

**23** Do you assign science homework to the <TIMSS class>?

Yes  No   
 Fill in **one** circle only

If **No**, please go to question **28** 

**24** How often do you usually assign science homework to the <TIMSS class>?

Fill in **one** circle only  
 Every or almost every lesson   
 About half the lessons   
 Some lessons

**25** When you assign science homework to the <TIMSS class>, about how many minutes do you usually assign? (Consider the time it would take an average student in your class.)

Fill in **one** circle only  
 Fewer than 15 minutes   
 15-30 minutes   
 31-60 minutes   
 61-90 minutes   
 More than 90 minutes

**26** How often do you assign the following kinds of science homework to the <TIMSS class>?

Fill in **one** circle for each row  
 Never or almost never  
 Sometimes  
 Always or almost always

a) Doing problem/question sets

b) Finding one or more applications of the content covered

c) Reading from a textbook or supplementary materials

d) Writing definitions or other short writing assignments

e) Working on projects

f) Working on small investigations or gathering data

g) Preparing reports

**27** How often do you do the following with the science homework assignments for the students in the <TIMSS class>?

Fill in **one** circle for each row  
 Never or almost never  
 Sometimes  
 Always or almost always

a) Monitor whether or not the homework was completed

b) Correct assignments and then give feedback to students

c) Have students correct their own homework in class

d) Use the homework as a basis for class discussion

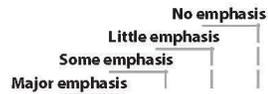
e) Use the homework to contribute towards students' grades or marks

## Assessment

28

How much emphasis do you place on the following sources to monitor students' progress in science?

Fill in **one** circle for each row



- a) Classroom tests (for example, teacher made or textbook tests) ----- ○ -- ○ -- ○ -- ○
- b) National or regional achievement tests ----- ○ -- ○ -- ○ -- ○
- c) Your professional judgement ----- ○ -- ○ -- ○ -- ○

30

What item formats do you typically use in your science tests or examinations?

Fill in **one** circle only

- Only constructed-response ----- ○
- Mostly constructed-response ----- ○
- About half constructed-response and half objective (e.g., multiple-choice) ----- ○
- Mostly objective ----- ○
- Only objective ----- ○

29

How often do you give a science test or examination to the <TIMSS class>?

Fill in **one** circle only

- About once a week ----- ○
- About every two weeks ----- ○
- About once a month ----- ○
- A few times a year ----- ○
- Never ----- ○

If **Never**, you have completed the questionnaire ●

31

How often do you include the following types of questions in your science tests or examinations?

Fill in **one** circle for each row



- a) Questions based on knowing facts and concepts ----- ○ -- ○ -- ○
- b) Questions based on the application of knowledge and understanding ----- ○ -- ○ -- ○
- c) Questions involving developing hypotheses and designing scientific investigations ----- ○ -- ○ -- ○
- d) Questions requiring explanations or justifications ----- ○ -- ○ -- ○

# Thank You

## for completing this questionnaire

## Appendix C

### Identification of Inquiry-Based and Didactic Science Instruction Questionnaire

Dear Participant,

My name is Lynn Martin and I am a doctoral candidate at Indiana University of Pennsylvania. As a requirement for completion of my doctorate degree, I am working on a dissertation entitled "Relationship Between Teacher Preparedness and Inquiry-Based Instructional Practices to Students' Science Achievement: Evidence from TIMSS 2007".

The purpose of this quantitative study will be to gain a greater understanding of science teachers' preparedness to teach science content and their instructional practices. This study will examine the relationship between science teachers' preparedness to teach specific science content and their instructional practices in the science classroom to the science achievement of eighth grade science students in the United States as demonstrated by the Third International Mathematics and Science Study 2007 (TIMSS 2007).

As part of this study, I will be using the teacher questionnaire section of the TIMSS 2007. Sections of the questionnaire ask the TIMSS teacher population to respond to questions regarding instructional methods. I will be identifying questions that indicate the use of inquiry-based instruction and traditional instruction.

For the purpose of inter-rater reliability, I am asking you to complete the following survey. You are eligible to participate in this study because you are a secondary science teacher with teaching experience. I am asking you to identify questions/statements as either inquiry-based or traditional. I would be very grateful if you could take a few minutes to respond to this survey and return it to me by September 21, 2009.

The Indiana University of Pennsylvania supports the practice of protection for human subjects participating in research. There are no known risks associated with this research. Your participation is voluntary. Your name will not be associated with any results and your response will be coded to ensure anonymity. All of your responses will be kept confidential. There is no penalty for not participating.

All of your responses on the survey will be kept confidential. No one, except my faculty sponsor, Dr. George Bieger, and me will have access to the data. All data will be kept in a locked file cabinet in my home office for at least three years in compliance with federal regulations. When analyzing and presenting the data, all data will be coded and participants will be identified with a pseudonym in order to protect your anonymity.

Please accept my sincere thank you in advance for your cooperation in this study.

Sincerely,

Lynn A. Martin

## Definition of Terms

Inquiry-based Instruction- Since the National Science Education Standards (NSES) is at the center of U.S. science education improvement, it is well to consider its definition of inquiry-based instruction for this study: Inquiry-based instruction engages students in making observations; posing questions; reviewing what is already known in regards to experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; communicating the results; identifying assumptions; using critical and logical thinking; and considering alternative explanations; processing information, communicating with groups, coaching student actions, facilitating student thinking, modeling the learning process, and providing flexible use of materials. (National Research Council (NRC), 1996 p. 23)

Didactic Instruction- Didactic instruction traditionally has been conceptualized as the transmission of facts to students, who are seen as passive receptors. This instruction typically uses lecture format and instructs the entire class as a unit. Knowledge is presented as fact where students' prior experiences are not seen as important. Moreover, instruction does not provide students with opportunities to experiment with different methods to solve problems, but primarily uses a drill and practice format with a foundation on textbooks.

Directions: Please identify the following as either inquiry-based instruction, didactic instruction, both, or neither by placing an X in the corresponding box.

	Inquiry-	Didactic	Both	Neither
--	----------	----------	------	---------

	Based			
Textbooks are used as the primary basis for lessons.				
Textbooks in are used as a supplementary resource for lessons.				
Students listen to lecture-style presentations.				
Students working on problems with teacher guidance.				
Students working on problems on their own without teacher guidance.				
Listening to the teacher re-teach and clarify content/procedures.				
Students taking tests or quizzes.				
Students participating in classroom management tasks not related to the lesson's content/purpose				
Students observe natural phenomena and describe what they see.				
Students watch the teacher demonstrate an experiment or investigation.				
Students design or plan experiments or investigations.				
Students work together in small groups on experiments or investigations.				
Students conduct experiments or investigations.				
Students read their textbooks or other resource materials.				
Students memorize facts and principles.				
Students use scientific formulae and laws to solve routine problems.				
Students give explanations about something they are studying.				
Students relate what they are learning in science to their daily lives.				
Using the computer to do scientific procedures or experiments.				
Using the computer to study natural phenomena through simulations.				
Using the computer to practice skills and procedures.				

Using the computer to process and analyze data.				
Completing homework assignments that require students to do problem/question sets.				
Completing homework assignments that require students to find one or more applications of the content				
Completing homework assignments that require students to read from a textbook or supplementary materials.				
Completing homework assignments that require students to work on small investigations or gathering data.				
Completing homework assignments that require students to prepare reports.				
On science tests or examinations questions are based on knowing facts and concepts.				
Completing homework assignments that require students to write the definitions or other short writing assignments.				
Completing homework assignments that require students to work on projects.				
On science tests or examinations questions are based on the application of knowledge and understanding.				
On science tests or examinations questions involve developing hypotheses and designing scientific investigations.				
On science tests or examinations questions require explanations or justifications.				

The End