# Multilevel Modeling of Factors that Influence Mathematics Achievement in Ghana: A Secondary Analysis of TIMSS 2007 and 2011

by

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## Abstract

The purpose of this study was to examine which student, teacher, and principal variables best explained the performance of the population of Grade 8 students in Ghana. This study was necessitated by the consistent low performance of Ghana's grade eight students in TIMSS since 2003. Ghana, as a country, ranked second last, second last, and last for the 2003, 2007, and 2011 TIMSS assessments.

A probability sample of Grade 8 students in a probability sample of schools participated in the TIMSS 2007 (5,294 students nested within 162 schools) and 2011 (7,323 students nested within 160 schools). The students responded to the mathematics achievement test for which a matrix item and student matrix sampling design was used. The students, teachers, and principals responded to their respective questionnaires. Since the students were selected from classes that were nested within schools, HLM analyses were used to analyze the data. However, only one class was selected from each school in each year. Consequently, 2-level HLM analyses were conducted. Prior to the analyses, the maximum likelihood with expectation maximization (EM) algorithm was employed to replace all the missing values at both the student level and teacher/principal level for both 2007 and 2011,and exploratory factor analyses conducted for clusters of similar items in the three questionnaires to reduce the number of predictor variables. The final numbers of variables were 40 student and 40 teacher/principal variables in 2007, and 15 student and 37 teacher/principal variables in 2011. The final parsimonious HLM model contained 20 student variables and five teacher/principal variables which accounted for 27% of the student variance and 51 % of the teacher/principal variance in 2007; the corresponding numbers for 2011 were nine, seven, 20%, and 54%. The change in the number of variables in the final models for the two years is due to changes made in the questionnaires. These changes precluded comparing the 2007 and 2011 results other than to say the variance explained at the student level and at the teacher/principal level were similar in each year (approximately 20% at the student level and 54% at the teacher/principal level). Taken together, it was concluded that lack of proper preparation of teachers in rural areas, questionable school climate and safety, emphasis on lower rather than higher thinking skills, inconsistent use of homework, failure to engage students in their learning, lack of progress of girls, lack of students' interest and confidence in mathematics, and students' lower educational aspiration contributed to Ghana's low performance on the TIMSS 2007 and 2011 assessments. Implications for practice and recommendations for research are provided.

## Dedication

I dedicate this doctoral dissertation to my beautiful wife Bonosa for the encouragements, love, patience, support, and understanding. I also dedicate this work to my lovely daughters Gloria, Michelle, and Seyram.

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# CHAPTER 1

# INTRODUCTION

In this era of global competitiveness, each country is preparing and training its citizens, especially children, so that they can gain competitive edge over others. This has led to several reforms and transformations in the economic, education, financial, and social policies of several countries. One such policy concerns the type and quality of education given to the students, with particular emphasis on the teaching and learning of mathematics; science; and information, communication, and technology (ICT). Mathematics is considered to be the foundation for success in many aspects of life because there cannot be any meaningful development without knowledge of mathematics (MoESS, 2007). Students' achievement in mathematics is often considered necessary for the success of the future of a country (Baker & LeTender, 2005; Wobmann, 2003). Moses and Cobb (2001) suggested that the knowledge of mathematics will play a vital role in the 21st century because it will serve as the path to political and cultural power. Therefore the training and preparation of students to do well in mathematics has become a fundamental goal of education for most countries (Mullis, et al., 2012).

To be sure that their students are given the right kind of instructional and educational opportunities as their peers in other countries, countries participate in national and international assessments in literacy (reading and writing), mathematics, science and in some cases, social studies. Examples of international assessments that assess mathematics and science are the Trends in International Mathematics and Science Study (TIMSS; International Association for the Evaluation of Educational Achievement (IEA), 2011) and the Programme for International Student Assessment (PISA; Organization of Cooperative and Economic Development (OECD), 2012). Participating countries at the end of each testing cycle are provided with their assessment results and those of other countries. In addition, the countries are provided with detailed information about the national context and the curriculum and instructional process of their country and other participating countries. The context and curriculum information can be used to help interpret the achievement of students and to track and monitor changes in curriculum and instructional activities over time. This information is collected using student, teacher, and principal questionnaires.

Due to the importance of mathematics, the government of Ghana has recently implemented measures to ensure that all Ghanaian students acquire the mathematical skills, insights, attitudes, and values they will need to become successful in their chosen careers and daily life. These measures were introduced as a result of Ghana's participation in TIMSS since 2003. While TIMSS assessments and background questionnaire are administered at the fourth and eighth grade levels, Ghana decided to participate only at the eighth grade level since Grade 8 is the grade before which students are screened for high school. The intent was to examine Grade 8 students' achievement in mathematics and science in Ghana using an international benchmark and to compare Ghana's level of achievement to the level of achievement of the remaining countries that participated in the TIMSS in 2003, 2007, and 2011 (Anamuah-Mensah, Asabere-Ameyaw, & Mereku, 2004). Participating in the TIMSS also provided Ghana with information about the context in which mathematics is taught in Ghanaian schools and to allow identification of strengths and weaknesses in the teaching and learning of mathematics in Ghana.

Overall, Ghana's performance in mathematics as measured by the 2003 TIMSS was poor. Ghana ranked 45$^{th}$ out of 46 countries. Following this performance, the Ministry of Education developed and implemented a new mathematics curriculum alongside the re-structuring of teacher education in Ghana. Whereas the average performance in mathematics improved by 33 scale points on the 2007 TIMSS, Ghana again ranked second from bottom of the 59 countries that participated in TIMSS 2007. Further, the mathematics results released by IEA for the TIMSS 2011 indicated that Ghana was ranked at the bottom in the ranked list of 63 participating countries (Mullis, et al., 2012).

Several researchers from different participating countries have conducted secondary data analysis of the TIMSS data to understand and model the factors that influence mathematics achievement (Azina & Halimah, 2012; Chepete, 2008; Mohammadpour, 2012; Pangeni, 2014; Papanastasiou, 2000; 2002; Skouras, 2014). However, studies on factors that influence the mathematics achievement of Ghanaian students on both TIMSS and other national examinations are limited in terms of scope and number. Apart from Ministry of Education sanctioned reports, the only study using the TIMSS data was conducted in 2010, when Frempong (2010) used the Hierarchical Linear Model (HLM) statistical technique to analyze the TIMSS 2003 data. The findings of Frempong's (2010) study indicated that there was significant variation among schools in the mathematics achievement of their students. The findings also revealed that the most successful students in mathematics were males, who have highly educated parents, high academic aspirations, like mathematics, are confident learning mathematics, and attend schools located in towns but not in villages (Frempong, 2010).

**Purpose of the Study**

Consequently the purpose of this study was to determine which factors measured in the student, teacher, and principal questionnaires administered as part of TIMSS 2007 and 2011 predict the performance of Ghanaian grade 8 students on the TIMSS 2007 and 2011, respectively.

**Research Questions**

This study was guided by the following research questions:

1) What combination of student-level and school-level characteristics best explained students' mathematics achievement in Ghana in TIMSS 2007?
2) What combination of student-level and school-level characteristics best explained students' mathematics achievement in Ghana in TIMSS 2011?
3) Was the strength of association between the student-level characteristics and mathematic achievement similar across the years 2007 and 2011?
4) Was the strength of association between school and classroom characteristics and mathematics achievement similar across the years 2007 and 2011?

HLM analyses were used to identify factors that affect mathematics achievement of 8$^{th}$ grade students using the 2007 and 2011 TIMSS datasets from Ghana. Specifically for each year, a two-level HLM model was developed using students' background information and classroom/teacher/school contextual factors to account for the variation of Grade 8 students' mathematics achievement both within (level 1) and between schools (level 2). Special attention was paid to predictor variables that can be manipulated so as to inform government educational policy and to start conversations among curriculum planners and developers, teacher education institutions, and school policy makers. Finally, by examining the patterns of relationship between mathematics achievement of 8$^{th}$ grade students and background and contextual factors across the 2007 and 2011 assessments, information about change will become available which can be used for future planning.

**Significance of the Study**

How to improve students' achievement in mathematics has received enormous public support following the poor performance of Ghanaian students in TIMSS 2003 and other national examinations (Anamuah-Mensah, Mereku & Asabere-Ameyaw, 2004; Anamuah-Mensah, Mereku & Ghartey-Ampiah, 2008). As indicated above, apart from one study conducted using TIMSS 2003 data, no studies have been conducted using the TIMSS 2007 and 2011 data from Ghana. The TIMSS 2007 and 2011 databases provided the largest set of international mathematics achievement and background data for Ghana's grade eight students (Martin & Mullis, 2012). This study is the first attempt to identify factors that influenced mathematics achievement among Ghana's Grade eight students in TIMSS 2007 and 2011. In contrast to summarizing the findings from the international reports (Anamuah-Mensah, Mereku & Asabere-Ameyaw, (2004); Anamuah-Mensah, Mereku & Ghartey-Ampiah,(2008)), the HLM procedure used to analyze the data for this dissertation takes into account the fact that students are nested within schools and estimates the effects of each factor at each level simultaneously. This will provide a comprehensive picture about the learning of mathematics in Ghana that can be used to help improve mathematics learning in schools in Ghana.

The findings of this study will also have significance for other developing countries with low performance in international assessments. Given the absence of research findings related to students' mathematics achievement in developing countries, developing countries rely on research findings from developed countries to implement their educational reform policies (Riddell, 1997). The reliance on the research findings from developed countries can be problematic because countries differ in terms of national and local contexts, culture, and financial resources (Bryan, Wang, Perry, Wong, & Cai, 2007; Delaney, 2000).

Third, this study will contribute to the education research in Ghana, since, with the exception of Frempong (2010) study; there are no major studies of this kind in Ghana. Using Hierarchical Linear Modeling technique to analyze a nationally representative achievement data within an international context provides an important step to researchers in the field of educational research and particular for similar national and international studies.

**Definition of Terms**

*Mathematics achievement*: For the purposes of this study, mathematics achievement is defined as the total mathematics score of each student who took the TIMSS 2007 assessment and each student who took the 2011 assessment.

*Eighth-grade students*: In the TIMSS study, eighth-graders are the students enrolled in the upper of the two adjacent grades that contained the largest proportion of 13-year old students at the time of testing. In Ghana, these are the students at the Junior High School (JHS) Form 2.

**Organization of the Dissertation**

The dissertation is organized in 6 chapters. A brief overview of the literature is presented in Chapter 1 to set the context of the study. This is followed in turn by the problem statement and its accompanying research questions, the significance of the study, and the definitions of terms used in the dissertation. Chapter 2 contains an overview of the educational system in Ghana followed by a description of the TIMSS report and the corresponding Ministry of Education in Ghana reports concerning the performance of Ghana on the 2007 and 2011 TIMSS assessments. Chapter 2 concludes with a review of the related literature on students' background characteristics and their attitudes towards mathematics, classroom and teacher characteristics, and school environment characteristics that have been found to be associated with mathematics achievement. The method followed to conduct the study is presented in Chapter 3. Included in

Chapter 3 is the research design, including a detailed description of the data sources and Ghana's TIMSS samples for 2007 and 2011, and identification of the dependent and the independent variables together with the descriptive statistics for each of the content and cognitive domains. A description of the Hierarchical Linear Modeling (HLM) and the equations associated with each level follows.

Chapter 4 includes the results and interpretation of the HLM analysis for TIMSS 2007. Chapter 5 describes the results and interpretation of the TIMSS 2011 data. Lastly, Chapter 6 begins with a summary of the problem statement, the methods used, and the results. The results are then discussed in terms of the literature reviewed. The limitations of this study and the conclusions drawn in light of the limitations follows. The chapter concludes with implications for practice and recommendations for future research.

# CHAPTER 2

# LITERATURE REVIEW

This chapter gives a brief overview of the educational system in Ghana, background information about TIMSS projects and assessments, and Ghana's TIMSS report and results. It will also review literature related to factors that influence mathematics achievement. The chapter concludes with the variables that will be investigated in this study.

## Educational System in Ghana

Education is one of the essential pillars in the development of every nation's economy and man-power (Klitgaard, 1986). Ghana, a developing nation, is doing everything possible to make its education free and accessible to every Ghanaian child of school age. This attempt has seen a lot of policy directions in the hands of different political leaders since independence of Ghana in 1957. In 1996, the Free Compulsory Universal Basic Education (FCUBE) program was launched in fulfillment of the 1992 constitutional mandate (FCUBE Policy Document, 1996). The FCUBE program focus was on the following areas: access to and participation in school; curriculum; teacher preparation and motivation; quality assurance through inspection and supervision; education for employability; health; and governance, planning, and resource management (FCUBE Policy Document, 1996). Following reforms in 2007, the number of years spent at the secondary schools was increased to 4 years, but this was reverted to three years after the presidential elections in 2008. Also, the elimination of payment of school fees in all public basic schools in 2005, the introduction of a school feeding program as well as the supply of free school uniforms and free laptops to school children are some of the important policies Ghana's education system has witnessed.

Currently Ghana operates on a 6-3-3-4 educational system: 6-year primary schooling beginning at the age of six; 3-year junior high school level; 3-year senior high school or technical/vocational institution; and 4-year University. This structure is also described as basic education (elementary and middle schools), secondary education (high school), tertiary education (college/university), and non-formal education, though not much is done or heard about the non-formal education (Anumel, 2012). More recently, mandatory pre-primary education (pre-school and kindergarten) have been implemented. As a result of the new education system, the basic education level includes 2-year preschool, 2-year kindergarten, 6-year primary schooling (Grades 1-6), and a 3-year junior high school (Grades 7-9).

According to Anumel (2012), policies such as elimination of schools fees and the introduction of school feeding programs in the public schools led to an increase in enrollment from 83.3% in 2010-11 to 96.4% in 2011-12 of eligible primary students and from 70.2% to 86.3% of eligible junior high students. The total enrollment in 2011-12 was 7,028,299 students in 23,770 preschools and kindergartens, 19,723 primary schools, and 11,709 junior high schools.

Though there have been several improvements in education in Ghana as a result of policies implemented by the previous and current governments, the education system still has some challenges (Anumel, 2012). The increased enrollment at all levels of education calls for expansion in infrastructure (more schools and classrooms, adequately resourced laboratories and libraries), adequate learning and teaching materials, and more prepared teachers. There is also the need to introduce information and communication technology as a subject at the basic level through to the tertiary level to meet the current trends of economic development. Though the education ministry receives the bulk of the national funds annually, the resources needed to meet the challenges at the basic level is not enough to match the increasing rate of enrollment.

*Language of Instruction*

During pre-school, kindergarten, and the early stages of primary education (Grades 1-3), the local language of the community in which the school is located is used as the language of instruction and English is taught as a subject. From Grade 4 onwards, English is the language of instruction and the Ghanaian languages are studied in schools depending on the local language of the community in which the school is located. French is also being taught in schools to at least the ninth grade.

*Mathematics Curriculum at the Basic level*

In Ghana, the teaching and learning of mathematics is compulsory at the pre-tertiary levels of education. There cannot be any meaningful development in virtually any area of life without the knowledge of science and mathematics (MoESS, 2007). Due to the importance of mathematics, the government is putting measures in place to ensure that all Ghanaian students acquire the mathematical skills, insights, attitudes, and values that they will need to become successful in their chosen daily lives and careers (MoESS, 2007). Various attempts have been made to improve the performance of Ghanaian students on both national and international tests. For instance, in 2002, the government embarked upon a comprehensive review through the establishment of the Anamuah-Mensah National Education Review Committee (Anumel, 2012; Agyei & Voogt, 2010), whose recommendations were implemented in 2007. The key focus of this committee was on mathematics and science curriculum development and textbook production so that the country's education would be competitive globally.

The new mathematics curriculum that was introduced in 2007 was based on the twin premise that all pupils can learn mathematics and that all need to learn mathematics (MoESS, 2007). It was aimed at equipping all students with knowledge of and application of basic mathematical knowledge and skills (Anumel, 2012). The curriculum provides information on the content (topic) and skills the students are to learn and teaching, learning, and evaluation activities and the time allocated to these activities. The primary school mathematics curriculum is divided into units and designed to cover the six years of primary education while the junior high school mathematics curriculum is also structured in units to cover three years.

According to the curriculum implemented in 2007, mathematics at the primary school emphasizes mathematical knowledge and skills that will help students develop competencies in basic numeracy to make them beneficial to the society (Anumel, 2012). As such, 40% of the instructional time should be devoted to knowledge and understanding and 60% devoted to application. The skills taught at this level include: using numbers competently; reading and interpreting data; reasoning logically; solving problems involving calculations and mathematical reasoning; and communicating effectively with others using accurate mathematical data and interpretations (Anumel, 2012).

Mathematics at the junior high school level builds on the knowledge and competencies developed at the primary school. Students at the junior high school level are expected to move beyond and use mathematical ideas in investigating real life situations (MoESS, 2007). The junior high school mathematics curriculum is structured to cover the following content areas: Numbers and Investigation with numbers; Geometry; Estimation and Measurement; Algebra and Statistics and Probability. According to the Ministry of Education, Science and Sports, 2007:

> *Numbers* covers reading and writing numerals in base ten, two, and five and the four basic operations on them as ratio, proportion, percentages, fractions, integers and rational numbers. Investigations with numbers provide opportunity for students to discover number patterns and relationships, and to use the four operations meaningfully. *Geometry*

covers the properties of solids and planes, shapes as well as the relationship between them. *Estimation and Measurement* include practical activities leading to estimating and measuring length, area, mass, capacity, volume, angles, time and money. *Algebra* covers algebraic expressions, relations and functions. These concepts are developed to bring about relationship between numbers and real-life activities. *Statistics and Probability* involves students in collecting, organizing, representing, and interpreting data gathered from various sources, as well as understanding the fundamental concepts of probability so that they can apply them in everyday life (MoESS, 2007, p.iii-iv).

The new mathematics curriculum implemented in 2007 also called for transforming the teacher-centered approach of teaching and learning to a more participatory approach where students can develop their skills through experimentation and application of problem solving skills (Ampadu, 2014). Students at this level of education are expected to acquire the ability to analyze, compare, distinguish, identify significant points, generate, and design new ideas and solutions as well as making recommendations (Anumel, 2012).

Ghana's participation and performance in the TIMSS in 2003 and 2007 prompted reforms in the mathematics and science curricula that are still on-going. Some of these reforms include the inclusion of higher cognitive skills such as synthesis and evaluation (Anumel, 2012) in the junior high school curriculum as well as the reduction of content material covered in schools. Also, whereas the number of mathematics test items used in national and school assessments that mainly required memorization and recall of facts has been reduced, the number of items requiring the application of mathematical knowledge and skill increased (Anumel, 2012). Further, mathematics and science teachers across the country are receiving in-service training on teaching and learning skills that are based on modern theories and contemporary methods of teaching and learning and on the creation of test items that call for application and analysis of mathematical and scientific concepts.

*Teacher Education in Ghana*

Following the educational reforms in 2007, the teacher training colleges became colleges of education and currently there are 38 colleges of education in Ghana. The colleges of education provide a common three-year pre-university teacher training program to potential teachers to enable them to acquire the skills and knowledge necessary to teach with the new curricula. Teachers who graduate from three-year programs at the colleges of education are awarded a diploma in basic education, which qualifies them to teach at the basic education level (Anumel, 2012). However, teaching at the secondary level requires a diploma or a first degree obtained after studying at a polytechnic or university. The diploma requires at least two years study and the first degree requires 4 years. For a teaching job at the tertiary institutions (polytechnics and universities), one needs a master's or a doctorate degree in the relevant discipline.

To promote the teaching and learning of mathematics, science, and technology at the basic education level and also to provide the country with adequate numbers of mathematics and science teachers, the government selected 15 colleges of education to specialize in the training of mathematics and science teachers (Anumel, 2012). The minimum admission requirements for three-year teacher education programs in colleges offering science and mathematics as major subjects include the following: prospective teachers must pass English, mathematics, and either social studies or the Ghanaian language, as well as two elective subjects in science, agriculture, or any technical subject during the secondary schooling (MoESS, 2007).

At the primary level (grades 1–6), general classroom teachers typically teach all subjects. However, in some upper primary classes (grades 4–6) and at the junior high level (grades 7–9), teachers' are subject-specific, and specialized training in mathematics and science education is required to teach these subjects.

Though there is in place the new curriculum and policy to produce adequate numbers of mathematics and science teachers for the basic education level, there are still some challenges. Some of these challenges include: general shortage of mathematics and science teachers in the country; refusal of mathematics and science teachers to accept postings to schools in rural areas; absence of instructional materials, equipment, laboratories, and computers (Anumel, 2012); and the inability of teachers to incorporate information and communication technology (ICT) in their lessons due the lack of computers (desk tops, laptops, tablets) even though the new curriculum mandates the teaching of simple concepts and the application of ICT; ( Agyei & Voogt, 2010; Anumel, 2012). Ampadu (2014) conducted an in-depth analysis of Ghanaian junior high school mathematics teachers' beliefs and examined if there is relationship between those beliefs and the way teachers' implement the new mathematics curriculum. He found that while the mathematics teachers are knowledgeable about the new curriculum and the changes to be made, the way they implemented the new curriculum was problematic in the sense that majority of the teachers have not been able to conceptualize the requirements and ideals of the new curriculum into their classroom discourse. Consequently, despite the presence of the new curriculum, students in Ghana continue to perform poorly in mathematics and science on both national and international assessments such as the Basic Education Certificate Examinations (BECE), the West African Secondary Schools Certificate Examinations (WASSCE), and TIMSS (Anamuah-Mensah, Mereku, & Asabere-Ameyaw, 2004; Anamuah-Mensah, Mereku, & Ghartey-Ampiah, 2008).

*Monitoring Student Progress in Ghana*

Unlike other African countries such as Tanzania where students are tested at the end of primary education, there is no high stakes testing at the end of primary education in Ghana. However, at the end of three years junior high school (Grade 9), all students sit for the BECE which is a national examination conducted by the West African Examination Council (WAEC). This examination is important because it serves as a basis for selection into senior high schools. According to the basic statistics released by the Ministry of Education in 2006, no more than 40% of the junior high school leavers passed the BECE and were admitted into the senior high school.

Another high stake examinations that students in Ghana take is the (WASSCE), which is a regional examination conducted by the WAEC. The WASSCE is taken at the end of three years secondary education (Grade 12) and the results are used for admission into the universities, polytechnics, colleges of education, and other non-tertiary and diploma awarding institutions. This examination is very important because the secondary school students see the tertiary education degree as the passport to elite status. Further, there are also only a few educational slots in the tertiary institutions despite a large number of students. Consequently, every student wants to do exceptionally well on the WASSCE. However, the increase in the number of private universities and professional institutions is helping to make tertiary education more accessible to those who can afford to attend these institutions, which charge higher fees in contrast to the public universities, where the fees are subsidized by the government.

In addition to the BECE and WASSCE, some Ghanaian students sit for other assessments that are administered at specific times to evaluate the schools curricula. These assessments include the national education assessments of numeracy and literacy for primary schools; the

TIMSS for second year junior high school students (Grade 8); and school-based examinations conducted at the end of each term in all schools throughout the country. The only assessment that specifically targets performance and gains in mathematics and science in the country is TIMSS (Anumel, 2012).

The implementation of the nine-year free compulsory basic education has made it mandatory for all students in Ghana at the basic level to be promoted automatically to the next class, irrespective of their performance on tests (FCUBE, 1996). While this promotion policy is strictly adhered to in all public basic schools, the situation is different in the private schools, where non-performing students repeat the same grade for the next school year. I am of the opinion that the automatic promotion in public schools is a contributing factor to the poor performance of Ghanaian students on both national and international examinations and future reforms must re-visit the automatic promotion of students in public schools.

**TIMSS Projects and Assessments**

The practice of conducting large-scale international achievement assessments dates back to the post World War II era (Phan, 2008). According to Phan (2008), the first large-scale international achievement assessment, the Pilot Twelve-Country Study, was conducted in 1961 with the support of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). UNESCO conducted the Pilot Twelve-Country Study with the idea that although educational systems cannot be transferred, ideas, good practices, and systems developed under one set of conditions could lead to improvement in other systems where the conditions were different. This study assessed the achievement of 13-year-old students in five subject areas: mathematics, science, reading comprehension, non-verbal ability, and geography. The 12 countries that participated in this study included; Belgium, England, France, Finland, Federal

Republic of Germany, Poland, Scotland, Israel, Sweden, Switzerland, United States, and Yugoslavia. The success of the first large-scale international achievement assessment served as a spring board for several other international assessments such as those conducted by the International Assessment of Education Progress (IAEP), the Organization for Economic Co-operation and Development (OECD), and the International Association for the Evaluation of Educational Achievement (IEA). Since Ghana participated in only the IEA assessments of mathematics and science, only a description of these assessments and Ghana's participation in them is provided here.

The IEA conducted the First International Mathematics Study (FIMS) in 1964 and the First International Science Study (SISS) in 1970-71. The Second International Mathematics Study (SIMS) and the Second International Science Study (SISS) were conducted in 1980-82 and 1983-84 respectively. The IEA from then on has conducted regular assessment of mathematics and science achievement together at one time in cycles of 4 years. Consequently, a combined survey consisting of mathematics and sciences, the Third International Mathematics and Science Study (TIMSS) was administered in 1994-95 for students at specified levels of pre-tertiary education. A study based on the same technical framework and similar to TIMSS 1995 referred to as TIMSS-Repeat or TIMSS-R was conducted in 1999. The aim of the TIMSS-R was to re-assess Grade 8 students' achievement in mathematics and science so as to identify any trends in students' achievement since 1995.

In the years 2003, 2007, and 2011, TIMSS was re-named Trends in International Mathematics and Science Study. These assessments were conducted in over 60 countries from all around the world to provide comparative information about the educational achievement of Grades 4 and 8 students across the participating countries so as to improve the teaching and learning of mathematics and science. TIMSS also provides "comparative perspectives on trends in achievement in the context of different educational systems, school organizational approaches, and instructional practices" through the collection of rich array of background information (Anamuah-Mensah, et al., 2008, p.1).

According to Alejandro (1999), TIMSS is regarded as the biggest, most comprehensive, ambitious, and extensive international comparative educational assessments ever conducted because it focuses on every important aspect of mathematics and science learning. For instance in 2003, TIMSS study involved over 360,000 students, over 38,000 teachers, over 1,200 school principals from the 46 participating countries, and as many as 1,500 contextual variables were measured in addition to student achievement (Martin, 2005). In 2007, the number of students assessed increased to approximately 425,000 from 59 participating countries. According to Martin and Kelly (2004), TIMSS assessments provide a thorough investigation of participating countries curricula and their implementation in the classrooms. Chepete (2008) concluded that the TIMSS assessment is a valid and reliable measure of students' achievement and hence policy makers and educational practitioners can use the information and indicators from TIMSS to improve their national educational systems.

However, some researchers have raised critical issues concerning the use of large-scale comparative assessment studies such as TIMSS (Finn, 1992; Bracey, 1997; Wolf, 1998; Zuzovsky, 1999). Some of the issues raised include cultural differences among the participating countries might influence their national pattern of schooling and hence the testing procedures adopted by TIMSS might not be appropriate for some countries' usual testing practices, and the complex coding algorithms employed in scoring of TIMSS test items and the translation of items into different languages might produce lower inter-rater consistency and questionable reliability estimates. Holliday (1999) suggested that it would be more appropriate and useful to compare the results of the assessments and performance of students from countries that are culturally and economically similar. Wang (2001) questioned the validity of using the reports from TIMSS data in projecting a country's achievements rankings. Wang argued that the design and construction of the instruments, curricular inequalities, and statistical outliers should be of concern when using TIMSS results as the yardstick for school reforms. LeTender, Baker, and Akiba (2001) suggested that the important thing for users of the IEA assessments is to identify effective teaching strategies and ways of improving the instructional activities in the native cultural background rather than trying to change the indigenous educational system to be like the educational systems that produced students with better achievement.

In an attempt to address some of these issues concerning the validity and appropriateness of common test items for all countries, the IEA stated that "…To ensure the reliability, validity, and comparability of the data through careful planning and documentation, cooperation among participating countries, standardized procedures, and rigorous attention to quality control throughout. The data are collected according to rigorous scientific standards detailed in manuals, and countries received training every step of the way…" (TIMSS, 2007, pp. 27-28). The then chairman of IEA, realizing the importance of countries participating in the TIMSS assessments suggested that "More than just league tables, the TIMSS data position achievement in an international context where it can be considered from multiple perspectives" (Alejandro, 1999, p. 2). A similar position was taken by Ferrini-Mundy and Schmidt (2005) when they suggested that international assessments such as TIMSS and PISA provide data about students' performance as well as on several contextual variables that serve as rich resources for researchers in mathematics education.

Ghana participated for the first time in TIMSS 2003 to get the opportunity to examine its students' achievement in science and mathematics using an international benchmark and to also compare this achievement to that of other countries (Anamuah-Mensah, Asabere-Ameyaw, & Mereku, 2004). Participating in the TIMSS also provided Ghana with rich information on the context for which mathematics and science are taught in Ghanaian schools and allow the identification of any strength and weakness in the teaching and learning of these subjects. Since 2003, Ghana has participated in the TIMSS conducted in 2007 and 2011.

**Highlights of Ghana's TIMSS Report and Results**

At the end of each testing cycle, IEA releases the TIMSS results for mathematics and science. Following the release of these results, the ministries of education in majority of the participating countries conduct follow-up analyses on their results so as to inform curriculum changes and other educational practices and policies. The Ministry of Education (MoE) in Ghana published the reports about the results and performances of its grade 8 students in TIMSS 2003 and 2007. It is worthy to note that though the IEA has released the results and databases for TIMSS 2011, the Ministry of Education in Ghana has not yet published its report for TIMSS 2011. Given this, the summary of the findings that will be presented here are mainly from the reports for TIMSS 2003 and 2007.

In Ghana, 5,114 Grade 8 students in 150 schools sampled across the country participated in TIMSS 2003 (MoE, 2004). The Ghana sample consisted of 55% boys and 45% girls. The head teachers as well as the mathematics teachers of the students also took part in the study by providing information about the context in which the teaching and learning of mathematics took place in the schools. The Ministry of Education report (MoE, 2004) provided the following information about the performance of Ghana's grade 8 students in TIMSS 2003:

- Ghana's overall performance in mathematics was poor and this poor performance was such that Ghana ranked 45th out of 46 countries;
- The mean percentage correct on all the mathematics test items for each participating Ghanaian student was 15%;
- Only 9% and 2% of the students reached the low and intermediate international benchmarks, respectively. This means that no Ghanaian student reached the high and advanced international benchmarks;
- Ghana's grade 8 students' performance was strongest in the content areas of Number and Data, while their weakest areas were in Algebra, Measurement and Geometry; and
- In all the content areas, the boys outperformed the girls.

The MoE report (2004) also provided information about contextual factors from the TIMSS databases that were positively correlated with students' performance in mathematics. According to the report (MoE, 2004), there was a positive correlation between the level of parental education and the achievement of students in schools. The report (MoE, 2004) also reported positive correlation between mathematics achievement and the following students' background characteristics: educational aspiration, self-confidence, students' valuing of mathematics, time spent on homework, home educational possessions, use of testing language at home, and the feeling of safe in schools. There was also a positive correlation between mathematics achievement and the head teachers and subject teachers' perceptions of school climate. Similar findings were reported by studies conducted in countries such as Malaysia, Nepal, Greece, Singapore, and Botswana (Azina & Halimah, 2012; Pangeni, 2014; Skouras, 2013; Mohammadpour, 2012; Chepete, 2008).

In 2007, Ghana was represented by 5,294 Grade 8 students sampled from 163 schools. While the performance of the Ghanaian sample in mathematics in TIMSS 2007 improved by 33 scale points over TIMSS 2003, the level of performance was still among the lowest among participating countries (MoE, 2008). The average score of 309 in mathematics again ranked Ghana second from the bottom of the 59 countries that participated in TIMSS 2007. In terms of the international benchmarks, only 4% and 17% of the Ghanaian students reached the intermediate and low international benchmarks; no Ghanaian student reached the high and advanced international benchmarks. In terms of content areas, Ghana's performance saw relative improvements in Algebra, Number, and Data, but performed significantly below the country's average in Geometry. Geometry still remained a weaker content area for Ghanaian students in TIMSS 2007, which is similar to the findings of the report for the TIMSS 2003. According to the report for Ghana (MoE, 2008), overall boys performed better than girls in all the four content domains in mathematics. In terms of positive correlates to mathematics achievement in TIMSS 2007, the findings were similar to what was reported in the MoE 2004 report for the 2003 TIMSS (MoE, 2008).

Even though the Ministry of Education in Ghana has not yet released its national report for TIMSS 2011, the results released by IEA showed that Ghana was ranked at the bottom when the 63 participating countries were ranked according to their performance (Mullis, Martin, Foy, & Arora, 2012). This comes as a surprise because, as described above, the Ministry of Education in Ghana developed and implemented new mathematics curriculum and re-structured teacher education with the introduction of the Basic Education Assessment System (BECAS) after the TIMSS 2003. The new curriculum stressed modern teaching methods and strategies as well as the development of test items that called for higher cognitive abilities (MoESS, 2007). With these interventions in place, it was expected that the country would perform better or show some significant improvements over the years and especially on the TIMSS 2011. This finding suggests that all is not going on well insofar with the teaching and learning of mathematics in Ghana. Could the low performance of mathematics in the country be due to the revised curriculum, teaching methods, teachers, students, and/or a combination of some or all of these factors? As indicated, this study attempts to find an answer to this question by using the questionnaire data and the assessment results for TIMSS 2007 and 2011.

**Factors that affect Educational Achievement**

The study of educational effectiveness of a school system and schools dates back to the 1960's. During that period the first wave of educational effectiveness research was conducted in the Western countries (Riddell, 2007). This first wave of educational effectiveness research likened the school process to an input-output function of a manufacturing factory which was designed to measure the impacts of individual variables on educational achievement (Coleman 1966; Plowden 1967). A prominent feature of the first wave of research differentiated the influence of students' background factors on academic achievement as compared to school factors, which can be manipulated by policymakers. The findings suggested that school factors had little influence on educational achievement compared to students' background factors. However, studies by other researchers (Hill & Rowe, 1996; Ma & Klinger, 2000; Martin, Mullis, Gregory, Hoyle, & Shen, 2000; Raudenbush & Willms, 1995; Rumberger & Palardy, 2004; Rogers, Ma, Klinger, Dawber et al., 2006) found that schools do matter and made a difference but there was no consensus concerning the extent to which schools made a difference and the sources of the difference. This non-consensus is mostly due to the fact that most studies that relied on the traditional input-output approach modeled the individual variables ignoring the nested structure of the educational system. Further and in contrast to the findings for the western countries, Heyneman (1976) compared the results from Uganda with the more industrialized countries and found that the overwhelming influence on students' achievement was the quality of the schools and teachers.

According to Riddell (2007), from the late 80's onwards, a second wave of school effectiveness research emerged in industrialized countries that moved from the traditional input-output approaches to focus on process variables such as teaching style. This approached relied more on educational theory and searched for individual process variables that were found to be significant in predicting students learning and achievement. The focus on process variables and the classroom is partly due to the frustration of not detecting significant causal relationships between students' achievement and such variables as the class size, the teaching and learning materials available, and the teachers' level of education (Riddell, 2007). However, this second type of school effectiveness research did not have much influence on educational effectiveness research in developing countries because they still relied on the input-output approach and the influence of individual variables on students learning achievement. In a review on 'what school factors raise achievement in the third world?' Fuller (1987) found the following process variables as being related to students' achievement: library activities, duration of instructional activities, and instructional quality. In contrast, he found individual teacher's salary, class size, and laboratories were not related to students learning and achievement. Other researchers also questioned the validity of some of the conclusions from studies on the total effect of school-level variables on learning achievement by distinguishing between developing and industrialized countries (Baker, Goesling, & LeTender, 2002; Hanushek & Luque, 2003).

Beginning from the late 80's, a third wave of research into the effectiveness of schooling on learning outcomes began (Riddell, 2007). This third wave of research is marked by taking into consideration the nested nature of the data specifically that, students are nested in classrooms that are nested within schools. This was made possible by the introduction of statistical techniques that accounted for the natural clustering inherent in any educational system (Raudenbush & Bryk, 2002; Snijders & Bosker, 1999; Goldstein, 2003). This wave of research centered on the interrelationships among variables within and between the nested levels, and in which students of varying backgrounds are nested within classrooms of different sizes, in different schools, taught by different teachers in different locations in different countries. Some findings from this third wave of research were in sharp contrast to some of the findings from the earlier waves of research because the former approaches assumed that the influence of different treatments due to clustering on students were zero. For instance the earlier findings that school level factors exerted a greater influence on learning achievement than the students' background factors in developing countries were contested when the same data were reanalyzed using multilevel modeling techniques (Riddell, 2007).

Following these different waves of research into educational effectiveness and quality, a number of conceptual models that model student learning achievement as a function of students' background and school characteristics have been developed and used in research into school effectiveness (Creemers, 1994; Rumberger & Palardy, 2004; Shavelson, McDonnell, Oakes, Carey, & Picus, 1987; Kaplan & Elliot, 1997; Kaplan & Kreisman, 2000; Koller, Baumert, Clausen, & Hosenfeld, 1999; Glasman & Biniaminov, 1981). Though there are numerous models of educational achievement reported in the school effectiveness literature, no one particular model of educational achievement has received extensive acceptance (Nelson, 2002).

For this present study, I adopted a conceptual framework that models the schooling process as a cluster system where students' learning achievement is influenced by students' background variables, classroom characteristics, and school characteristics. This model called 'Input-Process-Output' model (Rumberger & Palardy, 2004; Shavelson, McDonnell, Oakes, Carey, & Picus, 1987) described the educational system as comprised of three components: inputs, processes, and output. Figure 1 illustrates the input-processes-output model of education system adopted from Rumberger and Palardy (2004, p.9).

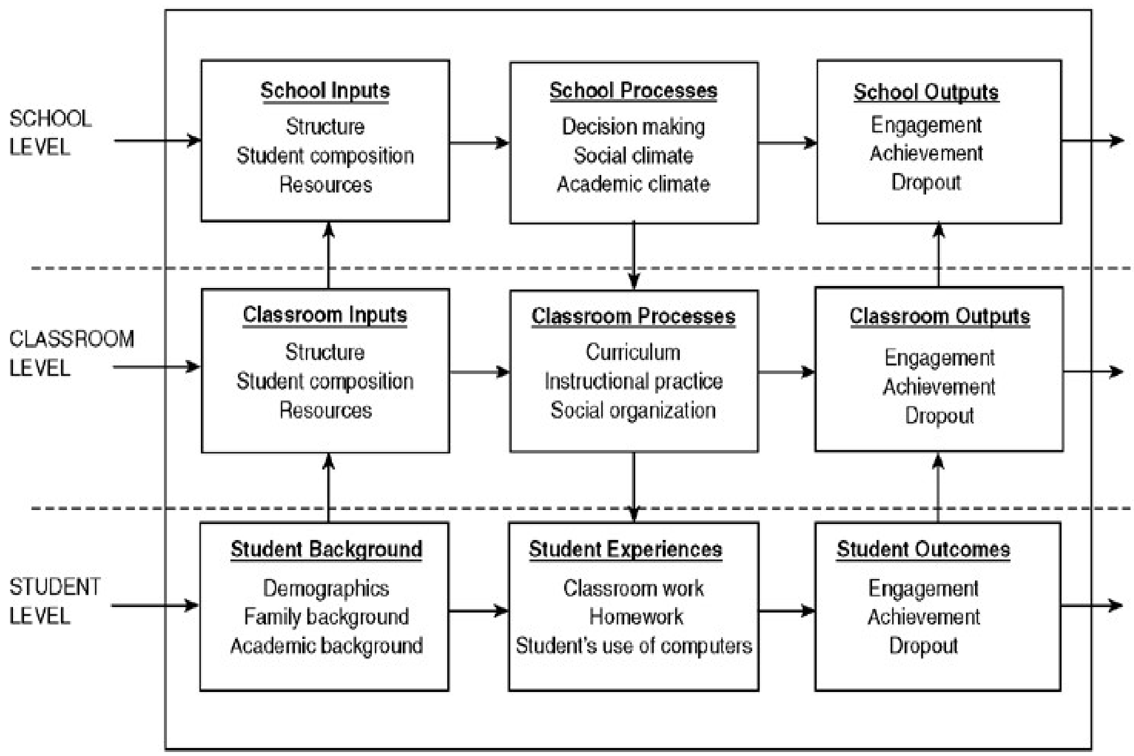


*Figure 1*: A multilevel input-processes-output model of an education system

The inputs of the model (Figure 1) are the financial and human resources that are available to the school and these include: student background (e.g., parents' level of education, number of books at home), teacher characteristics (e.g., certification and experience), and school quality. Its processes are the experiences the students encounter in the classroom and include characteristics such as teaching quality (e.g., teaching methods and instructional tasks), and academic and social climate. Finally the outputs of the model are the end products of schooling for students coming from different backgrounds, such as academic achievement, engagement, and dropout. The arrows in Figure 1 are indicating the direction of effect but not any cause-and-effect relationship.

This conceptual model was selected for the present study because it includes a wide coverage of educational achievement indicators and provides a complete conception of students' learning in the classroom environment (Chepete, 2008). This input-process-output model has been used frequently in recent studies that analyzed large scale data (e.g. Chepete, 2008; Kaplan & Elliott, 1997; Kaplan & Kreisman, 2000; Koller, Baumert, Clausen, & Hosenfeld, 1999; Rogers, Ma, Klinger, Dawber, et al., 2006). For instance, Kaplan and Kreisman (2000) used this model in their study using the TIMSS data to model and validate indicators of mathematics achievement. Some of the variables used in their study included: student level (*mathematics achievement, attitude towards mathematics, utility of mathematics, parents' educational level, and mother's expectation*); teacher level (*teacher's education level, teaching experience, method of instruction, and teacher collaboration with colleagues*); school level (*school climate, level of discipline, good facilities, recognition for outstanding teachers, and opportunities for continuing professional development*). Chepete (2008) also used this conceptual model to select variables in modeling the factors that predict mathematics achievement at the eighth grade in Botswana. In short this model gives more detailed information about how the various components of the educational system are related to one another and has been accepted as one of the prominent models for studies on educational effectiveness that aim at understanding and improving students' educational achievement.

## Factors That Influence Mathematics Achievement

Based on the conceptual model adopted for this study, empirical studies that have examined the impact of student-related factors, classroom characteristics, and school level factors that influence mathematics achievement are presented below.

## Student-Related Factors and Student Mathematics Achievement

Following the findings of earlier studies that suggested that the most influential factor on students' learning achievement is the students' family background, several studies have been conducted to examine the student and family background factors that impact on mathematics achievement (Chepete, 2008; Mohammadpour, 2012; Pangeni, 2014; Phan, 2008; Skouras, 2014). Of all the students' background variables, those that have been widely reported in the literature as influencing mathematics achievement include gender, socio-economic status, attitudes towards mathematics, parental education, and speak language of instruction at home (Else-Quest, Hyde, & Linn, 2010; Pangeni, 2014; Phan, 2008; Yang, 2003; Goforth, Noltemeyer, Patton, Bush, & Bergen, 2014).

### *Gender*

Research findings on gender gap in mathematics performance is mixed, with some studies favoring boys (Neuschmidt, Barth, & Hastedt, 2008; Frempong, 2010; Teodorovic, 2012), other studies favoring girls (Alkhateed, 2001; Azina & Halimah, 2012), and other studies favoring neither boys nor girls (Bessudnov & Makarov, 2013; Leahey & Guo, 2001). Specifically, the magnitude and direction of the achievement gap differs across tests, age, and countries. For instance, in a meta-analysis of the 2003 TIMSS and PISA data sets across 69 countries, Else-Quest et al. (2010) found that all the mean effect sizes in mathematics achievement were very small ($d < 0.15$). Similar findings were reported by Hyde, Lindberg, Linn, Ellis, and Williams (2008), who also found very small gender differences effect sizes ($d < 0.10$) in mathematics performance of over 7 million students from US state assessments. Further, the results of the PISA 2009 study indicated that boys performed significantly higher than girls in mathematics in 35 out of the 65 countries; girls outperformed boys in five countries; and in 25 countries, there was no significant difference between boys and girls (OECD, 2011). On the contrary, using the TIMSS (1995-2003) data to examine the impact of gender differences among eighth grade students from 16 countries, Neuschmidt, Barth, and Hastedt (2008) found out that boys outperformed the girls in all the 16 countries. Bielinski and Davison (2001) found that the gender gap although small, favored girls during elementary school, boys at high school, and neither group at middle school. However, a study conducted by Fennema, Carpenter, Jacobs, Franke, and Levi (1998) revealed that the gender difference in mathematics achievement is high during middle school and increases markedly at the higher school.

Analyzing a large data set of student performance on a standardised mathematics test in Russia, Bessudnov and Makarov (2013) observed that the mean difference in performance for boys and girls was negligible. Similar findings were reported in a study conducted by Xu and Farrell (1992) in China, though there is a limitation in the extent to which this study can be generalized because it only sampled students from schools in only one district in China.

Studies have shown that girls outperform boys in mathematics in United Arab Emirate (UAE) and Malaysia (Alkhateed, 2001; Azina & Halimah, 2012). According to Alkhateed (2001), girls from UAE outperform boys in mathematics and also show little anxiety in performing mathematics tasks unlike girls from most western countries. The superior performance demonstrated by girls in mathematics in UAE is a result of the positive belief system of parents towards their daughters' mathematics capabilities. Parents believe that girls can equally do well as boys in mathematics and as such they support and encourage their daughters to go into mathematics related courses and careers. Analyzing the TIMSS 2007 data from the Malaysian sample, Azina and Halimah (2012) found that girls performed significantly higher than boys. This finding is consistent with the performance of girls in the TIMSS 2007 mathematics test from countries like Armenia, Cyprus, Macedonia, Moldovo, the Philippines, and Singapore (Mullis, Martin, & Foy, 2008).

In Ghana, males consistently outperformed females in the 2003 and 2007 TIMSS study and in other national examinations (MoE, 2004, 2008; Frempong 2010). For instance, using the HLM technique to analyze the TIMSS 2003 data from Ghana, Frempong (2010) found that the most successful students on the TIMSS were males. Similarly, Chowa, Masa, Ramos, and Ansong (2013) found that male students had higher mathematics scores when they used HLM to analyze the baseline data from the YouthSave Ghana Experiment. Bassey, Joshua, and Asim (2011) examined gender differences of rural senior secondary students in mathematics in Nigeria. Their findings indicated that males outperformed females. Their study sampled students from only the Cross River State and hence the findings cannot be generalized to the entire Nigeria. On the other hand, Kulpoo (1998) using the data from the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) found that girls outperformed boys in mathematics in Mauritius. Generally, findings from several studies in this subject area agree that whereas males outperform females in mathematics tasks involving problems on measurement, spatial representation, complex problems, and propositions, females perform better than males on mathematics tasks involving computations, graph reading and simple problems (Beaton et al., 1996). In the same way, using the Scholastic Aptitude Test (SAT) and categorizing the maths test items into applied and abstract items, Harris and Carlton (1993) found that females outperformed males in abstract items whiles males outperformed females in applied items.

In an attempt to understand this gender difference in mathematics performance, several studies have also been conducted to investigate the reasons associated with this difference in mathematics achievement between males and females. For example, female students are reported to exhibit less confidence in their mathematical abilities than males (Leder, 1996; Norton & Rennie, 1998). Also the stereotyping of mathematics as a male domain can affect mathematics performance and cause anxiety on the part of females, thereby affecting their interest in mathematics (Else-Quest et al., 2010; Ethington, 1992; Norton & Rennie, 1998). Researchers have thus put the reasons for the gender differences in mathematics into two groups. Some researchers are of the opinion that the gender differences in mathematics achievement is the result of physical, mental, and other factors (biological discrepancies) (Else-Quest et al., 2010; Geary, Sauzts, and Liu, 2000); whereas others attribute this gender difference to external factors such as cultural and social factors like schooling (Fan & Li, 2008).

Following the second group of researchers who attribute the gender differences in mathematics to external factors, several studies have been conducted to examine the association between strategies employed, test item format, and test item difficulty and gender differences. For instance, Davis and Car (2001) attribute gender difference in mathematics performance to difference in strategies employed when solving mathematics problems. Their study showed that at early elementary school ages, while boys are able to recall information from memory and can use hidden cognitive strategies such as decomposition; girls are able to use obvious cognitive strategies such as counting of fingers to solve mathematics problems. On the issue of test item format, Bolger and Kellaghan (1990) found that boys outperformed girls in multiple-choice items whiles girls do slightly better than boys when the test is made up of open-ended items. However, findings from a study conducted by Wester and Henrisksson (2000) were contrary to the conclusion of Bolger and Kellaghan (1990) because they found that there was no significant difference in the performance of males and females when the test items format was changed. To examine the association between test item difficulty and gender difference, Bielinski and Davison (2001) used multiple-choice items from the maths test data of TIMSS 1995, National Educational Longitudinal Study (NELS) of 1998, and 1992 NAEP. They found that easy test items tended to be easier for females than males, whiles difficult items tended to be harder for females than males. Similar results were found by Penner (2003) when he used the TIMSS 1995 data to investigate the correlation between item difficulty and gender difference. The findings of this study indicated that as the level of difficulty of an item increases, boys perform better than girls. Therefore, if a math test is made up of more difficult items than easy items, then boys will outperform girls and the vice versa.

Taken together, as mentioned at the beginning of the discussion of research conducted to examine gender difference, the results reviewed are mixed. Thus, gender was included as a variable in the present study for both years to determine if there was a difference and if the difference was consistent across years.

*Socio-economic Status (SES)*

The effect of family socio-economic status on students' achievement in schools has received a lot of attention in the literature following the Coleman report of 1996 which indicated that student home background-related factors contributed significantly to student learning outcomes (Baker, Goesling, & LeTendre, 2002; Crane, 2001; O'Dwyer, 2005; Veenstra & Kuyper, 2004; White, 1982; Yang, 2003). Though evidence in the literature suggests a positive relation between academic achievement and SES, the variable SES has been measured differently by different researchers and the strength of this positive relationship can be weakened depending on the variables used or combined for SES (White, 1982). In a meta-analysis of 101 studies that investigated the relation between academic achievement and SES, White (1982) found that more than 70 different variables were used as measures of SES and he classified them into four groups:

- Traditional - using indicators such as parents' education and/or occupation, family income, possessions in the home;
- Home atmosphere – e.g., academic guidance given in the home, quality of testing language spoken at home, parents' aspirations for the child;
- School resources – e.g., salary of teachers, type and size of the community, average absenteeism; and
- Miscellaneous – e.g., ethnicity, family size.

White (1982) noted that measures of SES that included more than two indicators were more strongly correlated with academic achievement than any one indicator. He also noted that the home atmosphere measure for SES was more highly correlated with academic achievement than any single indicator or a combination of the other SES indicators.

Following the study of White (1982), Yang (2003) investigated the effect of different dimensions of SES on students' achievement by analyzing the effect of home possessions on students' achievement in mathematics and science from 17 countries that participated in the TIMSS 1999 study. He selected the indicators of SES from the TIMSS student questionnaire and employed multilevel structural equation modeling techniques in the analysis. One of the items on the TIMSS student questionnaire asks student to choose from a list of possessions that are in their homes. The first four items on this list are calculator, computer, study desk, and dictionary, which are common for all countries. The remaining items are included by the individual countries that reflect the SES of the family in their culture. Ghana's list included items such as electricity at home, possession of a car/motorbike/bicycle, tap water in the house, and chalk/blackboard in the classroom (Foy, Arora, & Stanco, 2013). Yang (2003) noted that SES was multidimensional and he found two distinct dimensions of SES. These dimensions are a general economic factor, which includes indicators such as parents' occupation and income, and a cultural capital factor, which includes indicators such as parents' education and home educational resources. Both factors were strongly related to academic achievement.

Similarly, O'Dwyer (2005) investigated the variation in mathematics performance and its correlates by using the 8$^{th}$ graders data of TIMSS 1995 and 1999 from 20 participating countries. She employed the two-level HLM technique to analyze the relationship between students' background variables and mathematics achievement. Her results showed that in 15 out of the 20 countries in 1995 and 14 out of 20 countries in 1999 there was a statistically significant relationship between mathematics achievement and the students' home background index. Though O'Dwyer used a different statistical technique and different indicators of SES, her findings were similar to the findings of Yang (2003). They both investigated the relationship between students' mathematics achievement and SES across multiple countries and found that while Hong Kong was the only country that showed a negative correlation between SES and students' mathematics performance, Slovenia posted the highest correlation between SES and students achievement. Baker, Goesling, and LeTendre (2002) investigated the relationship between SES and student achievement by using HLM techniques to analyze the TIMSS 1995 data from 36 countries made up of both developed and developing countries. They found that the family SES, indexed by mother's and father's educational level and the number of books at home, was positively related to students' achievement and similar across countries irrespective of the national income.

In Ghana, most grade 8 students attend schools where the majority of the students are from economically disadvantaged homes and of which 75% of them indicated that they have no access to computers at home (MoE, 2008). The MoE report indicated that mathematics achievement was higher for students who attended schools with fewer disadvantaged students. Using HLM techniques to analyze the 2003 TIMSS data for Ghana, Frempong (2010) found that male students coming from economically advantaged homes where their parents were highly educated and attended schools located in towns but not in villages obtained higher achievement scores in mathematics than their peers from economically disadvantaged homes.

*Parents' Educational Level*

Numerous studies have been conducted to investigate the influence of parental level of education on students learning outcomes (Crane, 2001; Campbell, Hombo, & Mazzeo, 2001; Strutchens, Lubienki, McGraw, & Westbrook, 2004; Yang, 2003). According to Crane (2001), parents' level of education can influence their children's mathematics achievement scores by providing them the opportunity to learn, such as paying for tutoring and creating a conducive learning environment at home that can aid the development of mathematical thinking and skills. Pangeni (2014) suggested that parents who are educated to a higher level have greater access to a combination of economic and social resources that can be used to help their children succeed in schools. Analyzing the TIMSS data for Turkish grade eight students, Yayan and Berberoglu

(2004) found a positive relationship between parental educational level and number of books at home and student achievement in mathematics. Schreiber (2002) using HLM techniques to analyze the TIMSS 1995 data from the USA concluded that students whose parents had higher levels of formal education scored higher on the mathematics achievement test than students whose parents had lower levels of formal education. Yoshino (2012) used the TIMSS 2007 data for USA and Japan to examine the relationship between students' self-concept, mothers' and fathers' educational level, the quantity of books at home, and their mathematics achievement. The findings of Yoshino (2012) showed that mothers' and fathers' educational levels were positively correlated with students' mathematics achievement.

According to the MoE report (2004) for Ghana, parents are the first models and most important educators for their children and as such their level of education may serve as a source of educational aspiration for their children. The results from the reports (MoE, 2004; 2008) indicated that higher levels of parents' education were associated with higher student achievement in mathematics. This finding was confirmed by Frempong (2010) when he used HLM techniques to analyze the 2003 TIMSS data for Ghana. His findings indicated that the most successful students in the mathematics test were students who have highly educated parents.

*Attitude toward Mathematics*

A number of studies have been conducted to investigate the relationships between students' attitudes toward mathematics and mathematics achievement (Broeck, Opdenakker, & Damme, 2005; House, 2003 & 2005; Ma & Kishor, 1997; Ma & Wilkins, 2003; Shavelson, McDonnell, & Oakes, 1989). Most of these studies reported that students' attitudes toward mathematics were positively correlated with mathematics achievement and continued study of mathematics. To support these findings, Broeck, Opdenakker, and Damme (2005) suggested that attitude strongly influences “the amount of time and intensity of the effort one spends on learning activities in the specific domain and eventually the learning results itself” (p.109). Hammouri (2004) studied the relation between attitudinal and motivational variables and mathematics achievement in Jordan by using structural equation modeling techniques to analyze the TIMSS 1999 data. The findings of his study showed a positive relation between mathematics achievement and students’ educational aspiration, attitudes toward mathematics, confidence in ability, and self-perception of the importance of mathematics. House (2003) studied the relationship between students’ self-beliefs and mathematics achievement among middle schools students in Hong Kong by using the TIMSS mathematics data. By adopting a two-stage clustering design, House (2003) found that students who reported that they enjoyed learning mathematics and valued the importance of mathematics in their daily lives tended to score higher on the mathematics test, whereas those who reported that mathematics was a difficult and boring subject obtained lower scores.

When House (2005) replicated his study by analyzing the 1999 TIMSS data for grade 8 students from Japan, he obtained results that confirmed the earlier findings that indicated a significantly positive correlation between students’ self-beliefs and mathematics achievement. Yoshino (2012) used the 2007 TIMSS data from the USA and Japan to examine the relationship between students’ self-concept of mathematics and mathematics achievement and found a positive relationship between students’ mathematics self-concept and mathematics achievement in both countries. However, the American students’ mathematics self-concept was found to be significantly higher than that of Japanese students at the same level of performance.

In contrast, in their meta-analysis of 113 studies that investigated the relationship between attitudes toward mathematics (ATM) and achievement in mathematics (AIM), Ma and

Kishor (1997) found a statistically significant positive, but weak correlation between ATM and AIM. They also found that although ATM causes AIM, the strength and magnitude of that causal relationship was too small to be considered for practical purposes. This weak relationship between ATM and AIM was also reported by Shavelson et al. (1989). In their study of the relationship between ATM and AIM across countries using the TIMSS dataset, Mullis, Martin, Gonzalez, and Chrostowki (2004) reported rather a puzzling association between the two in the sense that countries with high average achievement in mathematics had the majority of their students reporting low positive attitudes towards mathematics. Particularly, they found that high performing countries in the TIMSS tests had more students who reported relatively less confidence in mathematics and placed less value on the importance of mathematics in their daily lives. Conversely less performing countries had more students who expressed confidence in mathematics as well as valued mathematics more in their lives. Shen and Pedulla (2000) also investigated the relationship between students' self-perception and mathematics achievement using the TIMSS data. They found that the top-performing Asian countries had more students who had low self-perceptions about their competence in mathematics and tended to view mathematics as difficult. On the contrary, low performing countries had students who reported relatively high self-perceptions about performing well in mathematics. They speculated that this conflicting association between confidence in doing mathematics and mathematics achievement might be due to the distinctive characteristics of Asian culture. They claimed that students from Asian, especially Eastern Asian, at the younger age are taught to be humble even if they are successful in academic performance and this might make them look down upon themselves in relation to others. Schulz (2005) reported that students from high performing countries tended to show less positive attitudes and motivation towards mathematics. Mullis et al. (2004) suggested that high performing countries might be implementing a rigorous and demanding mathematics curriculum that leads to higher achievement but eliciting little interest and enthusiasm from their students for the subject. Notwithstanding this puzzling association between ATM and AIM, Mullins et al. (2004) concluded that internationally there is a positive relationship between attitudes toward mathematics expressed by students' self –confidence in mathematics and mathematics achievement.

Other research findings indicate that there is a gender differences in terms of attitudes towards mathematics. For instance, in a meta-analysis of studies that investigated gender comparisons of mathematics attitudes and affect, Hyde, Fennema, Ryan, Frost, and Hopp (1990) reported that males have a tendency to hold high positive attitudes towards mathematic with a small gap between males and females at the early stages, but the gap widens at the high school when males report higher self-confidence. It was also suggested that the lower performance of girls in mathematics compared to boys is as a results of differences in attitudes towards mathematics (Leedy, LaLonde, & Runk, 2003). Norton and Rennie (1998) reported that females tend to have less confidence in their mathematical abilities than their male students. Again, Frempong (2010) using HLM to analyze the 2003 TIMSS data for Ghana found that male students had high academic expectations, liked mathematics and expressed confidence in learning mathematics. This finding was consistent with the Ministry of Education report (MoE, 2004) which stated that students with higher educational aspirations and have high self-confidence in mathematics perform better in mathematics. However, the report (MoE, 2004) did not find any relationship between students' value for mathematics and mathematics achievement.

The TIMSS students' questionnaire ask students to indicate their agreements to a variety of attitude related issues such as: "I usually do well in mathematics", "I would like to take more mathematics in school", "I enjoy learning mathematics", "I learn things quickly in mathematics", "I like mathematics", "I need to do well in mathematics to get the job I want", and "I think learning mathematics will help me in my daily life." In an earlier study of the relationship between students' attitudes toward mathematics and mathematics achievement, Chepete (2008) used the students' responses to these questionnaires to derive three dimensions of attitudes: self-concept of ability, value or utility of mathematics, and educational aspiration. A detailed description of these composite variables and how items were selected to create the composite variables together with internal consistency indices will be presented in Chapters 3 and 4.

Though some researchers regarded the attitude variable as an input variable in the sense that positive attitudes towards mathematics influences mathematics achievement (Broeck, et al., 2005), others regard it as an output variable because good performance in mathematics promotes positive attitudes towards mathematics (Shavelson, et al., 1989). However, for this study I will use attitudes as an input variable.

*Frequency of Speaking Language of Instruction at Home.*

Research findings have suggested that when students frequently speak the language of instruction at home, they performed better on tests than their peers who spoke the language of instruction less frequently at home (Abedi & Lord, 2001; Darling-Hammond, 2000; Howie, 2004; Howie & Plomp, 2001; Lamb & Fullarton, 2002; Mullis et al., 2008). Specifically when the official language of instruction is different from the language spoken at home, students learning achievement is affected negatively. However, in a study to investigate the relationship between students' background factors and mathematics achievement using the 2007 TIMSS data for Malaysia, Azina and Halimah (2012) found that not speaking the language of instruction at home was significantly associated with high achievement in mathematics. They suggested that this finding indicated that the performance of Malaysian students in mathematics is not influenced by the language used but may be due to the fact that non-Malaysian students outperformed their Malaysian counterparts. They also indicated that the students who did not speak the language of instruction at home were mostly Chinese and Indians. In Ghana, the language of instruction from Grade four onwards is the English but students continue to study the local language of the community where the school is located. According to the Ministry of Education report (MoE, 2004; 2008), about 68% of Ghanaian Grade 8 students never spoke English or did so sparingly at home. The report also indicated that students coming from homes where English Language is always or almost always spoken outperformed students who never or spoke less English at home.

**Classroom Related Factors and Students Achievement**

Studies have shown that schools account for a considerable amount of variance of the within-school variation in students' achievement (Bosker & Witziers, 1996; Bryk & Raudenbush, 1992; Rowe & Hill, 1998; Townsend, 2007). Among all the school related variables, teacher and classroom variables account for the largest variations in students' achievement when the other background characteristics are controlled (Goldhaber, 2002; Hattie, 2005; Heyneman & Loxley, 1993; Lamb & Fullarton, 2002). Several studies have also examined the relationship between teacher characteristics and students achievement (Darling-Hammond, 2000; Akiba, LeTender, & Scriber, 2007; Goldhaber & Brewer, 1997). Apart from teacher characteristics, studies have also suggested that classroom characteristics such as class size, teaching approach, classroom climate, and classroom practices are important variables influencing students' achievements (Mohammadpour, 2012). Empirical studies that have been conducted to investigate the relationship between teacher and classroom characteristics and students achievement are reviewed in this sub-section.

*Teacher Characteristics*

Several empirical studies have been conducted to identify the attributes of teacher quality that are linked with higher students' achievement. Findings from these studies have identified teacher certification, education, subject matter and pedagogical knowledge, teaching experience, and beliefs as significantly related with higher student achievement (Darling-Hammond & Youngs, 2002; Akiba, LeTender & Scriber, 2007; Chepete, 2008; Kaplan & George, 1998; Rice, 2003; Wayne & Youngs, 2003; Wilson, Floden, & Ferrini-Mundy, 2002). Analyzing the NAEP data set, Darling-Hammond (2000) found that the teachers with full certification and a subject major predicted higher levels of students achievement in both reading and mathematics. Similarly, analyzing the 1988 National Education Longitudinal Study (NELS: 88) data from a group of secondary school teachers, Goldhaber and Brewer (1997) found that teachers who were certified in mathematics produced students with higher achievement in mathematics as compared to those with no certification in mathematics. Nye, Konstantopoulos, and Hedges (2004) supported this finding when they suggested that teachers' certification has real and positive effects on students' achievement.

In contrast, other studies found that subject-specific certification had little or no significant influence on students' achievement (Rice, 2003; Rowan, Correnti, and Miller, 2002). For example, analyzing survey data from Prospects: The Congressionally Mandated Study of Educational Growth and Opportunity (1991-94), Rowan et al. (2002) did not find any significant influence of subject specific qualification on elementary students' achievement growth in mathematics. Xin, Xu, and Tatsuoka (2004) used the rule-space method to find the association between students achievement and teacher qualification. They found that the teachers' qualifications, major field of study, and teaching experience were not positively correlated with students' achievement. Chepete (2008) used HLM to analyze the 2003 TIMSS data from Botswana and found that the teachers' qualifications, teaching experience, and major field of study were not important predictors of students' achievement.

A number of empirical studies have suggested significant and positive effects of teacher experience on students' achievement (Greenwald, Hedges, & Laine, 1996; Rice, 2003). Chidolue (1996) and Fetler (2001) noted a positive correlation between teacher's experience and students' achievement. Though there is positive relationship between teacher experience and students' achievement, this relationship is not linear. For instance the effectiveness of teachers to improve students' learning outcomes increases within the first three years of teaching, but no significant improvement in their teaching effectiveness was noted after three years of teaching experience (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2006; Rice, 2003; Rivkin, Hanushek, & Kain, 2005). Klecker (2002) did not find any relationship between students' achievement and teacher's experience when he analyzed the mean mathematics scores of eighth graders from the 2000 NAEP data.

Some studies have also used teachers' beliefs as an indicator of teacher quality because teachers' instructional activities are influenced by their beliefs. According to Kupari (2003), teachers who held the belief that mathematics is an abstract subject depended on procedural methods in their instruction that used rules and algorithms, whereas teachers who held constructive beliefs of mathematics took more time to understand the strengths and weaknesses of their students and adopted suitable methods to address their concerns. A similar suggestion was made by Staub and Stern (2002) when they said that the way teachers present their instructional materials is influenced by their beliefs. Wilson and Cooney (2002) also indicated that what is taught in the classroom, how it is taught, and what is learned in the classroom is greatly influenced by teachers' beliefs. Given the influence of teachers' beliefs on their instructional activities, some researchers have examined teacher characteristics and beliefs of high-achieving countries compared to lower-achieving countries. For example, Hiebert, et al.( 2005) found that mathematics teachers from high-achieving countries adopt a balanced attention to difficult content, conceptual understandings, and procedural skills, while teachers from the U.S. adopt instructional activities that are focused on lower level mathematical skills. Similarly, Sawada (1999) observed that mathematics instruction in Japan is primarily on the development of problem-solving strategies and as such the whole instructional period could be devoted for a single problem. Becker, Silver, Kantowski, Travers, and Wilson (1990) indicated that Japanese mathematics teachers tended to demonstrate multiple strategies for solving mathematics problem, and used manipulative learning aids in their instruction to help students adapt and develop flexible thinking about strategies to use for solving problems in mathematics (Kroll & Yabe, 1987).

House and Telese (2011) analyzed the TIMSS 1995 data to investigate classroom strategies that are significantly related to mathematics learning and achievement and found that students' learning and achievement were higher in classes where teachers thoroughly explained the rules and definitions, solved examples pertaining to new topics, and solved real life experiences related problems. Using HLM to analyze the 2003 TIMSS data from Ghana, Frempong (2010) found that students who achieved higher scores in mathematics were in classrooms taught by teachers who did not use calculators frequently and often provided students with the opportunity to demonstrate and explain their mathematical ideas.

Though studies have shown that teachers' instructional activities are influenced by their beliefs, other studies have also noted that teachers do not always practice what they believe. In a study to investigate teachers' beliefs and their mathematics instructional practices and activities, Raymond (1997) found that though the teachers in her study held non-traditional beliefs about mathematics, they were practicing something else. According to Raymond (1997) the non-traditional belief of mathematics meant that mathematics was a very dynamic subject which is problem driven that needs to be learnt through problem solving activities, and that every student is capable of learning mathematics. Similarly, in a study to investigate Ghanaian mathematics teachers' beliefs and practices concerning the implementation of a new mathematics curriculum, Ampadu (2014) found that Ghanaian teachers' perceptions of their classroom instructional activities and practices were not totally consistent with what they actually do. Specifically, Ampadu (2014) found that although mathematics teachers in Ghana professed that they are using student-centered approach to teaching, the majority of teachers were actually using teacher-centered approaches in their classrooms.

The measure of teacher quality across various national contexts is fraught with methodological challenges because teacher quality is defined differently in various countries. For instance, comparative studies by LeTender (1994, 1995) suggested cultural roles and identities of teachers differed across nations. Akiba, LeTender, and Scriber (2007) also suggested that patterns of national educational organizations and political priorities affect teachers' roles and approaches to teaching. However, Kaplan and George (1998) indicated that one way of determining mathematics teachers' quality is to focus on their certification, education, teaching experience, and attitudes. For the purpose of this study, the following measurable indicators of teacher quality were used: teacher certification, teaching experience, teachers' instructional practices, and teachers' beliefs.

*Classroom Characteristics*

The relationship between class size and students' achievement has been an ongoing debate. Glass and Smith (1978) published findings from a meta-analysis of 77 studies that investigated the influence of class size on student achievement. The findings from their study indicated that (a) on average, smaller classes were associated with higher students' achievement; (b) reduction in class size appeared to increase students' achievement depending on the initial class size – reducing class size from 10 to 5 students had a greater influence on students' achievement than reducing the class size from 30 to 25 students; and (c) the association between students' achievement and class size was similar across students irrespective of ability levels and age (Glass & Smith, 1978). Similarly, in the same year, the Educational Research Services (ERS, 1978) also conducted a review of 41 studies to investigate the relation between students' achievement and class size across different grades. The major findings of this review study were rather conflicting as expressed in the following conclusions: (a) the association between students' achievement and class size was a complex one; (b) the effects of class size on students' achievement resulted from a mixture of several variables such as teacher qualities, students' characteristics, school and class resources, content areas, and instructional objectives; (c) with an average of 25 to 34 students, the effect of class size on student achievement appeared to be insignificant at the primary level; and (d) smaller class sizes appeared to be more advantageous for students from less privileged backgrounds or students with lower academic ability. The dissimilarities between the findings of these two studies prompted the Educational Research Services in 1980 to criticize Glass and Smith (1978) for over generalizing their findings and concealing major distinctions in class size research (ERS, 1980). To this end, the Educational Research Services (ERS, 1980) called for further research on the relationship between class size and students' achievement. To add further confusion, the results of the meta-analysis study conducted by Slavin (1989) revealed that reducing class size alone will not bring about any significant difference in students achievement even at the primary levels.

Currently, because of the availability of international educational data, several studies have investigated the relationship between class size and students' achievement across countries. Using HLM to analyze the eighth grade math TIMSS 1995 data from nine countries (Australia, Canada, France, Germany, Hong Kong, Korea, Iceland, Singapore, and USA), Pong and Pallas (2001) studied the effects of class size on mathematics achievement. The findings indicated that while the Asian countries tended to have large class sizes (e.g., Korea had the largest average class size of between 50 and 54 students followed by Hong Kong and Singapore with an average class size of 35 to 40 students), these countries are always ranked at the top on the international maths achievement tests. In contrast, in western and European countries with average class sizes between 20 and 26 students performed less well. Pong and Pallas also showed that after controlling for classroom and school factors across the countries, Australia and Canada were the only countries outside of Asia where performance in mathematics was better in larger classes than in smaller classes. In contrast, students from smaller classes outperformed their peers from larger classes in the US (Pong & Pallas, 2001). This same finding was supported by Hanushek (1999) who reported that students perform better in classes with fewer students.

Wobmann and West (2006) investigated the effects of class size on 7$^{th}$ and 8$^{th}$ grade students' performance in mathematics and science using the TIMSS 1995 data from 11 countries. They noted a significance inverse association between class size and students' achievement in

Greece and Iceland, but no association between class size and achievement in the remaining nine countries. Interestingly students from Greece and Iceland tended to perform below the international average while students from the remaining countries tended to perform above the international average. The conclusion drawn by Wobmann and West (2006) was that the effects of class size on students' achievement depended on the educational system.

According to the Ministry of Education report (MoE, 2004), the average class size in Ghana was 37 for the 2003 TIMSS and there seemed to be a positive correlation between class size and students' achievement in mathematics and science. This positive association could be attributed to the fact that in rural areas in Ghana, classes are generally smaller and teaching is normally poor and of lower standard compared to urban areas where class sizes are larger and have better teaching and learning resources (MoE, 2004).

Another classroom characteristic that has received attention in the literature is the instructional quality. According to Shavelson et al. (1989), the quality of instruction in the classroom is concerned with the performance of teachers, the characteristics of textbooks, and other teaching and learning materials used. The quality of instruction and the instructional activities students engaged in influences the quality of mathematics learned in the classroom (Hiebert & Grouws, 2007). Hiebert and Grouws (2007) reviewed the literature on the influences of classroom mathematics instructional activities on students learning and achievement and suggested that when instruction emphasized conceptual developments, both mathematical skills and conceptual understandings were promoted. It is not surprising that current reforms in mathematics education across countries are seeking to replace traditional teaching methods that viewed students as passive learners with modern methods that view learning as a means of knowledge construction (Hiebert & Grouws, 2007). Stevenson, Lee, and Stigler (1986) suggested that the when students are exposed to rigorous mathematics content material, their learning improves. Additionally, the types of tasks students are engaged with in the classroom provide the context in which students learn to think about the subject matter, and different tasks may provide students with different cognitive opportunities (Henningsen & Stein, 1997). Thus, teachers should provide students with tasks that have the potential to influence and structure their thinking and broaden their views of the subject matter they are engaged in. To improve students' learning, Hiebert and Grouws (2007) suggested that teachers pay "explicit attention to connections among ideas, facts, and procedures" and to the "engagement of students in struggling with important mathematics" (p.391).

**School Level Factors and Students Achievement**

Analyzing the data from 1971 IEA's First International Science Study (FISS) from 19 countries, Comber and Keeves (1973) disputed the claims of the Coleman (1966) by indicating that the school quality indexed by instructional practices and resources had a direct relationship with students' achievement in middle and high schools across the countries. Heyneman (1976) compared the results from Uganda with the results of more industrialized societies to determine the influence of school on academic achievement and found that the overwhelming influence on students' learning achievement was the quality of the schools. This finding was confirmed by Heyneman and Loxley (1983) when they re-analyzed the IEA's data for the 19 countries that were used in Comber and Keeves (1973) study. Their study also revealed that the effects of school level factors on students' achievement in developing countries were very high. For example, in India, the school level factors and teacher quality accounted for a significant amount of variation in students' achievement. To further explore the relationship between school effects and students achievement in developing countries, Fuller (1987) reviewed a number of studies that looked at school factors that raise achievement in developing countries. According to Fuller (1987), after controlling for the effects of students' family background, schools accounted for a greater influence on students' learning and achievement in developing countries. Fuller (1987) attributed the greater influence of schools on students learning in developing countries to the lack of resources at the home and schools, and the social class structures in developing countries.

According to Lee and Shute (2010), one of the school level factors that is related to K-12 students' achievement is school climate. By school climate, they meant indicators such as classroom management and principal's leadership style. Studies have observed that students attending schools where the teachers and the principals portray the school climate as positive obtained higher achievement scores (Lubienski, Lubienski, & Crane, 2008). Similar findings were reported by the Ministry of Education of Botswana (MoE, 2005), which noted that average performance of students was significantly lower in schools where cheating, intimidation, vandalism, and profanity were reported than in schools without these problems.

Another school level factor that relates to students' performance is the school location. For instance, in sub-Saharan Africa, students who live far away from the school may not be able to afford the transportation costs to and from the school, which eventually affects school absenteeism and student achievement (Fentiman, Hall, & Bundy, 1999; Shabaya & Konadu-Agyemang, 2004). Both the Ministries of Education for Ghana and Botswana reported that students from schools in the urban areas outperformed students from schools in the rural areas (MoE, 2004; MoE, 2005). Similar results were noted by Frempong (2010), who used HLM to analyze the 2003 TIMSS data from Ghana. He found that students from schools located in towns (urban areas) outperformed their peers attending schools in the villages or rural areas. These results agree with the findings of Mandeville and Liu (1997) when they reviewed studies on the relationship between school effects and students' achievement, and concluded that students from rural areas or villages tended to be more educationally disadvantaged.

The TIMSS assessment measures the effects of school level factors by asking students, teachers, and principals to provide responses to items that focus on certain characteristics of their schools. Some of the items pertain to the locality of the school while others relate to the climate of the school (e.g., students behaviors, security, maintenance, and teacher job satisfaction). In the present study, the following school level factors were used as an indicator of school quality: school-location, availability of resources for mathematics, teachers' perception of the school climate, and principals' perception of the school climate. School location was measured by a single item, whereas the school climate variables are composite ones. Details on the composite variables are provided in the chapter on methodology.

**Selection of Variables for the Study**

Following the input-processes-output conceptual model adopted for this study (see Figure 1), variables were selected from the three levels of the educational process: student level, classroom level, and school level. At the student level, both students' background characteristics, attitudes toward mathematics, homework, and instructional activities were investigated. At the classroom level, teacher and classroom characteristics were also investigated. At the school level, school location, average school size, availability of resources for mathematics and the perceptions of teachers, and principals about the climate of the school were the variables investigated.

Tables 6 and 7 at the end of Chapter 3 (pp 78-81) provide the list of student, teacher, and principal variables considered in this study. The operationalization of these variables is provided in Table A1 and Table A2 in Appendix A. For example, gender was coded girls = 1 and boys = 2 as seen in Table A1. It is important to note that the variables considered are restricted to those included in the 2007 and 2011 TIMSS questionnaires, some of the variables are self-reported, and that some variables are measured by single items and others by a combination of items as shown in Tables 1A and 2A in Appendix A.

**Summary**

Following Ghana's low performance in mathematics achievement at the eighth grade in the TIMSS since 2003, gaining an understanding of factors that are related to mathematics achievement has become an important educational goal in the country. Several researchers have conducted studies over the years across different countries to examine the effects of contextual variables on students' mathematics achievement. Some of these contextual variables included students' background, teacher and classroom characteristics, and school related factors. The findings of these studies are, however, mixed.

The review of the literature revealed that the research findings on gender gap in mathematics performance is mixed, with some studies favoring boys (Neuschmidt, Barth, & Hastedt, 2008; Frempong, 2010; Teodorovic, 2012), other studies favoring girls (Alkhateed, 2001; Azina & Halimah, 2012), and other studies favoring neither boys nor girls (Bessudnov & Makarov, 2013; Leahey & Guo, 2001). Similarly, whereas some studies found a positive association between teachers' certification and subject major and students' mathematics achievement (Darling-Hammond, 2000; Goldhaber & Brewer, 1997; Nye, Konstantopoulos, & Hedges 2004), others found little or no association between teachers' qualification, and subject major and students' mathematics achievement.

In light of these mixed findings in the literature about the association between contextual factors and students mathematics achievement, and the fact that only one quantitative study has been conducted in Ghana, the present study was conducted to establish or provide evidence between the relationship between students' mathematics achievement and students' background and other contextual factors. More specifically, the effects of both students-, and teacher/principal-level variables listed in Tables 6 and 7 at the end of Chapter 3 (pp 78-81) on Ghanaian grade eight students mathematics achievement using the TIMSS 2007 and TIMSS 2011 data for Ghana.

# CHAPTER 3

# METHOD

This chapter is organised into three sections. The first section restates the purpose of the study and the research questions. The second section talks about the research design including the source of data for this study, the sample for the study, the achievement instrument, and the background questionnaires. Section three presents the data analyses that includes treatment of missing data, data reduction techniques, the variables for the study, sampling weights and the hierarchical linear modeling (HLM) analyses technique with the associated equations.

## Purpose of the Study

The purpose of this study was to identify which of the students' background, teacher characteristics, and school contextual variables measured in the TIMSS 2007 and 2011 predicted the performance of Ghanaian Grade 8 students in mathematics. This study was guided by the following research questions:

1) What combination of student-level and school-level characteristics best explained grade 8 students' mathematics achievement in Ghana in TIMSS 2007?
2) What combination of student-level and school-level characteristics best explained grade 8 students' mathematics achievement in Ghana in TIMSS 2011?
3) Was the strength of association between the student-level characteristics and mathematic achievement similar across the years 2007 and 2011?
4) Was the strength of association between school and classroom characteristics and mathematics achievement similar across the years 2007 and 2011?

HLM analyses were used to identify factors that affected mathematics achievement of $8^{th}$ grade students using the 2007 and 2011 TIMSS data sets from Ghana. Specifically, for each year, a series of two-level HLM models were developed using students' background information and teacher/classroom/school contextual variables to account for the variation of grade 8 students' mathematics achievement both within and between schools. Special attention was paid to predictor variables that can be manipulated so as to inform government educational policies.

**Research Design**

*Data Source*

This study utilized data from the 2007 and 2011 Trends in International Mathematics and Science Study (TIMSS). Ghana participated at the $8^{th}$ grade level in TIMSS in 2003, 2007, and 2011. The TIMSS 2007 and 2011 were the data sets used in this present study. The TIMSS 2007 and 2011 data sets for $8^{th}$ grade mathematics provided Ghana with rich and suitable information about the students' background, teachers, curriculum, and school characteristics that were used to model the relationship between students' mathematics achievement and background and contextual variables in the country.

*Sample for the Study*

To ensure that the students selected from the participating countries are representative samples, TIMSS employed a two-stage stratified sample design (Foy & Joncas, 2003). At the first stage, schools are selected with probabilities proportional to their sizes from the list of schools in the country that contain the Grade 8 students (Martin & Mullis, 2012). The schools in the list can be stratified according to demographic factors such as school type (public, private) and, urbanicity (urban, semi-urban, or rural).

At the second stage, one or two intact classes were randomly selected from each selected school. In the case of Ghana, only one intact class was selected from each of the sampled schools because majority of the schools in Ghana have only one class at each year. The mathematics teachers for the selected classes, the principals from the selected schools, and the sampled students in the selected schools are administered the respective questionnaires and, for the students, the achievement test.

Table 1 shows the number of participating schools, teachers, and the distribution of students together with the average mathematics performance for the 2007 and 2011 TIMSS. As shown, Ghana's TIMSS sample consisted of 163 mathematics teachers and 5,294 students in 163 schools in 2007 and 170 teachers and 7,323 students in 170 schools in 2011. The average performance for Ghana's grade 8 students in TIMSS expressed on a scale with mean 500 and standard deviation 100 was 309 in 2007 and 331 in 2011. Despite this increase, Ghana's rank dropped from second last in 2007 to last in 2011. However, the grade 8 students from the private schools in Ghana that constitute about 17% of the population of Junior High School students were not included in the TIMSS. Including the students from the private schools in the TIMSS would have possibly increased Ghana's score and its' subsequent ranking.

*Achievement Instrument*

In TIMSS 2007 and 2011, test items were designed to address four content domains in mathematics: number, algebra, geometry, and data and chance. The number content domain consisted of skills and understandings related to whole numbers, fractions and decimals, integers, and ratios, proportion, and percent. The major topic areas in algebra included patterns, algebraic expressions, and equations, formulas, and functions. The geometry content domain covered geometric shapes, geometric measurement, and location and movement. The data and chance content domain included data organization and representation, data interpretation, and chance (probability). The TIMSS assessment framework is such that 30% of the test items covered the number content domain, 30 % on algebra, 20% on geometry, and 20% on data and chance. The

TIMSS assessment items were also designed to address different cognitive levels, namely, knowing, applying, and reasoning. As for the content areas, 35% of the items measured knowing, 40% measured applying, and 25% measured reasoning. TIMSS

Table 1: *TIMSS 2007 and 2011 Students' Sample*

| | 2007 | 2011 |
|---|---|---|
| Number of schools | 163 | 170 |
| Number of students | 5,294 | 7,323 |
| Number of teachers | 163 | 170 |
| Number of girls | 2,422 (45.8%) | 3,501 (47.8%) |
| Number of boys | 2,868 (54.2%) | 3,822 (52.2%) |
| Average maths achievement | 309 | 331 |

assessment instruments for a particular testing year contain items that were released in the previous testing cycle, items common to the previous and current cycles that were not released, and new items. For example, the TIMSS 2011 mathematics test contained items that were released in 2007, items common in 2007 and 2011 that were not released, and items used for the first time in 2011. The use of previously released and previously unreleased items allows for a reliable measurement of trends in the learning and teaching of mathematics over time. The use of the common items allows linking of the 2007 and 2011 assessments. The TIMSS 2007 mathematics test for Grade 8 contained 238 items, of which 24 were first administered in 1999, 85 were first administered in 2003, and 129 items were new in 2007. Similarly, the TIMSS 2011 mathematics test for Grade 8 contained 303 items, of which 88 were items released in 2007, 124 were common in 2007 and 2011 but not released, and 91 were introduced in 2011 (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009).

Given the large number of test items for mathematics and a nearly equal number of science items, TIMSS employs a matrix sampling design such that each student is administered a sample of the items. In this procedure, each item is assigned to one of the unique 14 item blocks. Student test booklets are then assembled using different combinations of the item blocks in order to ensure subject content coverage. Each item block contains 12 to 18 items at the eighth grade. In TIMSS 2007, 8 of the 14 item blocks contained secure items from the 2003 TIMSS test that were to be used to measure change between 2003 and 2007 and the remaining 6 blocks contained new items for 2007. For the 2011 assessments, 8 of the 14 item blocks contained secure items from 2007 assessment to measure change between 2007 and 2011, and the remaining 6 blocks, which initially contained 2007 items that were released, contained new items for 2011. Each item block contains multiple-choice and constructed-response items. On average, each item block provides about 18 score points spread across 8 to 9 multiple-choice items (1 point), 3 to 4 short answer constructed-response items (1 point), and 1 to 2 extended-response items (1 or 2 points). The 14 mathematics blocks are distributed across 12 student booklets and students are randomly assigned to booklets. Tables 2, 3, and 4 display the TIMSS 2011 mathematics test by item type, content domains, and cognitive domains respectively.

To report on students achievement scores, TIMSS employed item response theory (IRT) scaling methods to link individual student responses to items from previous administrations so as to track their progress in mathematics achievement. In this case, a three-parameter IRT model is used in the case of dichotomously scored multiple-choice and short constructed-response items (Martins & Mullis, 2012). The generalized partial credit model (Martins & Mullis, 2012) is used for the extended constructed-response items. The fundamental equation for the three-parameter IRT model is expressed as:

$$p_{i\,(\theta)} = c_i + (1 - c_i)\frac{e^{D_{a_i(\theta - b_i)}}}{1 + e^{D_{a_i(\theta - b_i)}}}, \quad i = 1, 2, 3, \ldots, n,$$

Table 2: *TIMSS 2011 Mathematics Test Item Types*

| Item Type | Points | Items released in 2007 | Items common in 2007 and 2011 | Items introduced in 2011 | Total |
|---|---|---|---|---|---|
| Multiple- Choice | 1 | 50 | 66 | 52 | 168 |
| Constructed- | 1 | 27 | 45 | 37 | 109 |
| Response | 2 | 11 | 13 | 2 | 26 |
| Total | | 88 | 124 | 91 | 303 |

Table 3: *TIMSS 2011 Mathematics Items by Content Domains*

| Content Domain | Items released in 2007 | Items common in 2007 and 2011 | Items introduced in 2011 | Total |
|---|---|---|---|---|
| Number | 32 | 30 | 31 | 93 |
| Algebra | 17 | 46 | 23 | 86 |
| Geometry | 22 | 24 | 18 | 64 |
| Data and chance | 17 | 24 | 19 | 60 |
| Total | 88 | 124 | 91 | 303 |

Table 4: *TIMSS 2011 Mathematics Items by Cognitive Domains*

| Cognitive Domains | Items released in 2007 | Items common in 2007 and 2011 | Items introduced in 2011 | Total |
|---|---|---|---|---|
| Knowing | 28 | 52 | 27 | 107 |
| Applying | 45 | 42 | 42 | 129 |
| Reasoning | 15 | 30 | 22 | 67 |
| Total | 88 | 124 | 91 | 303 |

where $p_{i\,(\theta)}$ is the probability that a randomly selected examinee with ability $\theta$ answers item $i$ correctly,

$a_i$ is the item discrimination parameter,

$b_i$ is the item *i* difficulty parameter,

$c_i$ is the pseudo-chance level (guessing parameter) that represents the probability of examinees with low ability answering the item correctly,

*n* is the number of items in the test,

*e* = 2.718, and

*D* = 1.7, a scaling factor that make the logistics function as close as the normal ogive function (Hambleton, Swaminathan, & Rogers, 1991).

According to Muraki (1992), the generalized partial credit model is an extension of the two-parameter logistic model to polytomously scored items and the probability function for scoring in category *x* on item *i* of an examinee with trait level, $\theta$, for the partial credit model is expressed as:

$$p_{ix(\theta)} = \frac{exp[\sum_{k=0}^{x} a_i(\ \theta - b_{ik}\ \ )]}{\sum_{h=0}^{m_i} exp[\sum_{k=0}^{h} a_i\ (\theta - b_{ik})]},$$

where $m_i$ is the number of score categories minus one,

$b_{ik}$ is the difficulty parameter associated with score category $x$, and

$a_i$ is the item discrimination.

The score for each student is then computed by averaging the responses to items the student took and considering the difficulty and discrimination of each item.

Since each student responds only to items in one booklet, and not the entire assessment, TIMSS employs a complex psychometric scaling method to obtain the estimate of the score each student would have obtained had the student attempted all the items on the test. This complex scaling technique, known as item response theory scaling with conditioning and multiple imputations, is used to generate imputed scores for the items that were not administered to a student, conditional on the student background characteristics and their responses to the attempted items (Gonzalez, Galia, & Li, 2004; Martin, 2005). To counter the effect of errors inherent in this imputation method, TIMSS computes five different plausible values for each student for the full assessment and each of the four content domains and the cognitive levels. The plausible values are standardized to have a mean and standard deviation of 500 and 100 respectively, which make them comparable across test administrations. In this study, only the five plausible values for the total score for mathematics were used as the dependent variable. The HLM statistical package that was used for the data analyses is capable of incorporating all the five plausible values in its analysis. It does so by running the analysis five times for each set of plausible values and gives a final estimate for the average of the results from the five analyses.

*Background Questionnaires*

Since learning takes place within a context, TIMSS collects information about background and contextual factors that affects students learning in mathematics and science. The questionnaires focus on background and contextual variables that have been evidenced in the literature as important variables in improving students' achievement in mathematics and science. These factors include: type of school, school resources, instructional approaches, opportunity to learn, teacher characteristics, students' attitudes, and home support for learning (Mullis, et al., 2009). The TIMSS 2007 and 2011 contextual framework consisted of the national curriculum questionnaire, student questionnaire, mathematics teacher questionnaire, and the school questionnaire. The grade eight student mathematics questionnaire contained 18 forced choice questions that provide information about student background factors, home possessions, attitudes towards mathematics, and experience in learning mathematics and science, and perceptions about the school climate. As a result of cultural and social differences, some of the items on the questionnaire are adapted or omitted to suit the national context of a country. For example, items about the educational level of parents and home possessions are either modified to reflect the context of the country or omitted.

The mathematics teacher questionnaire consists of 28 forced choice questions that gather information about teachers' educational qualifications, licensure, teaching experience, professional development, pedagogical and instructional activities, and the implemented curriculum. Similar to the students' questionnaire, some items are either adapted or removed to reflect different national contexts.

The school questionnaire contained questions that ask the school's principal or headmaster to provide information about school climate, resources available for teaching and learning, the national curriculum, school location, and other information about the context within which mathematics is taught and learned. As in the previous questionnaires, some items are either adapted or removed to reflect the different national contexts.

**Data Analysis**

*Treatment of Missing Data*

In large-scale surveys the issue of missing data needs to be addressed before conducting statistical analyses. The presence of missing data could bias the results of a study depending on the method used to treat the missing values (Tomarken & Waller, 2005), the percentage of the data missing (Tabachnick & Fidell, 2007), and the pattern of the missing values (Allison, 2000; 2002; Cohen & Cohen, 1983). The 2007 and 2011 TIMSS datasets for Ghana have missing values at both the student and teacher/ school levels. An explorative analysis of the missing values for the 2007 data set indicated that as much as 6% of values were missing at the student level, and as much as 12% missing at the teacher/school level.

According to Chepete (2008), there are two main techniques that are mostly used in treating missing values. These techniques are deletion and substitution techniques. Two examples of the deletion techniques are *listwise* and *pairwise* deletions. In the listwise deletion method any cases with missing data in one or more variables are eliminated from the analysis (Allison, 2002). In the case of pairwise deletion, the analysis is carried out using all the cases that have scores on each variable or pairs of variables (Allison, 2002). Consequently, this will lead to different sample sizes for different variables depending on the percentage of missing data per variable or pair of variables, which will in turn lead to inconsistent estimates of true standard errors. According to Allison (2003), this sample size problem becomes more challenging when correlation matrices are to be used as inputs to linear modeling software because these matrices cannot be inverted.

Another way of handling missing values is to drop variables that have high percentages of missing values instead of dropping cases (Tabachnick & Fidell, 2007). This alternative is recommended when variables with higher percentages of missing values are not critical to the analysis.

With the substitution techniques, values are imputed for the missing values. The substitutions methods mostly used are those that impute values once and those that use multiple imputations. In the case of the former, values for the missing values are estimated by using available information such as the mean value and regression weights (Tabachnick & Fidell, 2007). In these procedures, the missing values are replaced with the mean of the variable or replaced with a predicted value estimated from a regression equation using other independent variables that have complete cases (Allison, 2002). The multiple imputation procedures involve iterative processes such as the maximum likelihood substitution method and the multiple imputation method.

Although the use of the multiple imputations method is increasing, the listwise deletion method is widely used in most studies because of its simplicity, robustness, and popularity. For example, the listwise deletion method is considered the most robust and leads to unbiased parameter estimates as compared to other methods such as pairwise deletion and the complicated multiple imputations methods if the data missing is completely at random (Allison, 2002; 2003; Roth, 1994). Phan and Kromrey (2006) in their study found that the statistical results from analysis that used the listwise deletion method were comparable with the results of studies that used a multiple imputation method. Similar results were found by Chepete (2008) who employed both listwise deletion and multiple imputation methods to analyse the 2003 TIMSS data from Botswana. However, the problem with listwise deletion, particularly when it leads to a large loss of subjects, is that the new population to generalize results to is not known. For example, a preliminary analyses of missing data using the listwise procedure led to a final sample size for the 2007 and for the 2011 data sets that were approximately 60% of the initial sample and there was no way to tell what population the remaining 60% represented.

Therefore, in this study, the maximum likelihood with expectation maximization (EM) algorithms was employed to replace all the missing values at both the student level and teacher/principal level for both 2007 and 2011. This is because employing the listwise deletion procedure would have resulted in 40% loss of the initial sample. Further, the results of the Little's MCAR test that test the null hypothesis that the data are missing completely at random was significant, indicating that the missing data are not missing completely at random. Using the listwise, pairwise, and regression methods would lead to biased estimates.

*Data Reduction Procedure*

Student Level

The grade eight student mathematics questionnaires contained a large number of variables including single items and items that were clustered together. An example of a cluster of items in 2007 TIMSS is the 12 items that were related to students' attitude towards mathematics. Students were asked "How much do you agree with these statements about learning mathematics"? 1) I usually do well in mathematics, 2) I would like to take more mathematics, 3) Mathematics is more difficult for me than for many of my classmates, 4) I enjoy learning mathematics, 5) Mathematics is not one of my strengths, 6) I learn things quickly in mathematics, 7) Mathematics is boring, 8) I like mathematics, 9) I think learning mathematics will help me in my daily life, 10) I need mathematics to learn other school subjects, 11) I need to do well in mathematics to get into the <university> of my choice, and 12) I need to do well in mathematics to get the job I want. The response options for all 12 items were “agree a lot”, “agree a little”, “disagree a little”, and “disagree a lot”. However, in TIMSS 2011, the number of items related to students’ attitudes towards mathematics was 19 with no change to the response options. There were also clusters of 17 instructional items and nine out-of-school activities items in TIMSS 2007, four home support items in 2011, and nine home possessions items, three items related to students’ perception of their school, and five items related to students’ safety in their school in both years.

Exploratory factor analysis (EFA) was conducted to determine if these clusters of items were unidimensional or multidimensional. Principal Component Analysis (PCA) extraction was conducted and Guttman’s rule that the number of factors is equal to the number of eigenvalue greater than or equal to one (Guttman, 1954) and the Cattell’s Scree test (Cattell, 1966) were applied to extract the eigenvalues for each cluster of variables to determine the number of factors to retain for each cluster. When the number was one, it was concluded that the cluster of variables was unidimensional. When the number of factors was two or more it was concluded that the cluster of variables was multidimensional. In the case of multidimensionality, Principal Axis Factoring (PAF) followed by varimax rotation and oblique promax transformation with k = 4 was used in an attempt to obtain a solution with simple structure that could be validly interpreted.

The results of the preliminary analysis indicated that in the case of the items in the students’ perception of the school, home support, and students’ safety in the school clusters, both Guttman’s rule of eigenvalue greater than 1 and the scree plot indicated unidimensionality.

Therefore, the items under each of these clusters were summed to create a total score. In the case of the instructional items and the out-of-school items, Guttman's rule and the Scree test indicated multidimensionality. However principal axis factoring followed by a varimax rotation and a promax transformation did not yield any simple and interpretable solutions. Hence, the individual items were considered separately in the HLM analysis described below.

Both Guttman's rule and Cattell's Scree test indicated that the nine home possession items loaded on two factors. Eight of the possessions excluding internet connection loaded on factor 1 and one item, internet connection, loaded on factor 2 in both the rotated and transformed solutions. An inspection of the descriptive statistics for the home possessions revealed that 91% of the students indicated that they had no internet connection at home. Further, the second factor is not a common factor. Consequently, the second factor was dropped and the eight possessions under factor 1 were summed to represent the home possessions variable.

Both Guttman's rule and the Cattell's Scree test revealed three factors for the 12 attitude items used in 2007 and the 19 attitude items used in 2011. Principal factor extraction followed by the promax transformation yielded a three factor pattern matrix with an interpretable simple structure. The three factors were labelled self-confidence, value of mathematics, and perceived difficulty with mathematics. Table 5 presents the factors with the factor pattern coefficients for the items loading on each factor as well as the reliability coefficients for the three derived variables. As can be seen from Table 5, Cronbach's alpha for the three factors were, respectively, 0.77, 0.74, and 0.61 for self-confidence, value for mathematics, and perceived difficulty in 2007 and 0.830, 0.815, and 0.755 in 2011. The correlation between the pairs of factors indicated that the three factors were moderately correlated. Specifically, in 2007, the correlation between self-confidence and value for mathematics was 0.389, between self-confidence and perceived difficulty was -0.270, and between value for mathematics and perceived difficulty was -0.194. Similar pattern of correlations between the factors were observed in the 2011 data (0.345, -0.204, -0.186, respectively).

Teacher/Principal

As was done in the case of the students' variables, the same exploratory factor analysis procedures were conducted on the following clusters of teacher/principal items: teacher's beliefs, teachers' instructional practices, teacher's perception of the school climate, teacher's perception of the school facility and safety, teacher's readiness to teach number, readiness to teach algebra, readiness to teach geometry, readiness to teach data and chance, math-related professional development, monitoring students' progress, item formats, type of questions, limiting maths instruction due to students factors, opportunity to learn number, opportunity to learn algebra, opportunity to learn geometry, opportunity to learn data and chance, principal's perception of the school climate, expected parental involvement, evaluation of mathematics teachers, and availability of resources for mathematics instruction. Both Guttman's rule and the Scree test indicated there was only one factor for each teacher/principal cluster of items. Therefore, the variables in each cluster were summed. The reliability coefficients for these clusters ranged from 0.59 for teacher's beliefs to 0.89 for school resources for mathematics instruction.

Table 5: *Factor Loadings of the three Student Attitude scales*

| Variable | Factor Loadings | | $r_{xx}$[a] |
|---|---|---|---|
| Factor 1: Self-Confidence | 2007 | 2011 | |
| I learn things quickly in Mathematics | 0.807 | 0.725 | 0.768 (2007) |
| I usually do well in mathematics | 0.780 | 0.753 | 0.830 (2011) |
| I enjoy learning mathematics | 0.700 | 0.540 | |
| I like mathematics | 0.697 | 0.507 | |
| I am good at working out difficult mathematics problems | - | 0.771 | |
| My teacher tells me I am good at mathematics | - | 0.753 | |
| My teachers thinks I can do well in mathematics | - | 0.638 | |
| Factor 2: Value for Mathematics | | | |
| I need to do well in mathematics to get into the <university> of my choice | 0.797 | 0.836 | 0.744 (2007) 0.815 (2011) |
| I need to do well in mathematics to get the job I want | 0.769 | 0.823 | |
| I need mathematics to learn other school subjects | 0.687 | 0.704 | |
| I think learning mathematics will help me in my daily life | 0.669 | 0.692 | |
| I would like to take more mathematics in school | 0.482 | - | |
| It is important to do well in mathematics | - | 0.591 | |
| I would like a job that involves using mathematics | - | 0.491 | |
| Factor 3: Perceived Difficulty | | | |
| Mathematics is boring | 0.755 | 0.630 | 0.608 (2007) |
| Mathematics is more difficult for me than for many of my classmates | 0.746 | 0.687 | 0.755 (2011) |
| Mathematics is not one of my strengths | 0.741 | 0.675 | |
| Mathematics makes me confused and nervous | - | 0.697 | |
| Mathematics is harder for me than any other subject | - | 0.692 | |
| I wish I did not have to study mathematics | - | 0.639 | |

[a] Cronbach's alpha

*Variables for the Study*

Taking into account the findings of the exploratory factor analysis, 40 student variables in 2007 and 15 student variables in 2011 were considered as predictor variables. Forty teacher/principal variables in 2007 and 37 teacher/principal variables in 2011 were considered as predictor variables. These variables included both single-item and composite variables. The outcome variable was total mathematics achievement that was indicated by the five plausible values. The lists of all the variables that were considered in the 2007 and in 2011 are presented, respectively, in Tables 6 and 7 (pp 78 – 81). More complete and detailed descriptions of the variables for both 2007 and 2011 are provided in Appendix A.

*Sampling Weights*

Given that the designs of TIMSS 2007 and 2011 involved unequal probabilities of selection, it was necessary to apply the appropriate sampling weights to the various levels of data when analyzing the data so as to produce results that reflect the characteristics of the population and obtain unbiased population estimates (Martin, 2005). The sampling weights reflect the probability of selecting each student and school, considering any stratification and adjusting for non-response (Foy & Joncas, 2003; Martin, 2005). The following sampling weights are provided in the TIMSS 2007 and 2011 databases: Senate, House, Total Student Weight, Math Teacher Weight, and the School Weight.

Whereas the Senate Weight is useful for international estimates such that each country is treated equally irrespective of the student population when making inferences and drawing conclusions at the international level, the House Weight is used when analyzing data from different countries to ensure that the weighted sample reflects the actual number of students from each country. The Total Student Weight (TOTWGT) is a composition of six factors, three of which are school, class, and student weighting factors; and three of which are non-participation adjustments at each of these levels. Application of the TOTWGT ensures that the various subgroups that constitute the country's sample are properly and proportionally represented in the population estimates for a country (Foy & Joncas, 2003; Martin, 2005). The Math Teacher Weight (MATWGT) is used when students and teacher data are to be analyzed together. It is also used to obtain estimates regarding students and their teachers. The School Weight (SCHWGT) is computed as the product of the inverse of the probability of selecting a school and the corresponding non-participation adjustment factor (Martin, 2005). For this dissertation, the Total Student Weight (TOTWGT) was used as the sampling weight at the student level and the Math Teacher Weight (MATWGT) used at the teacher/school level, given that inferences were to be drawn about the students and schools in Ghana,

*Hierarchical Linear Modeling of School Effectiveness*

As indicated in Chapter 2, school systems are best described as a nested system in which students are nested within classes which are nested within schools which are nested within school districts. For instance in Ghana, the multilevel nature of the schooling system is: students are nested within classrooms or by teachers; teachers or classrooms nested within schools; schools are nested within circuits; circuits are nested within districts; and districts are nested within regions.

Multilevel modeling methods have been developed that can sort out the effects of the predictor variables at the different levels (Kreft & Leeuw, 2004). Hierarchical Linear Models (HLM) is the most commonly used (Hox, 1998). The main objective of multilevel modeling is to reveal the specific relationship between lower-level variables (e.g., students) and the higher-level variables (e.g., teacher/school) and the dependent variable taking into account the relationships that may exist within and among the levels. In this dissertation, the Hierarchical Linear Modeling (HLM) analysis procedures were used to examine the within and cross-level effects of the predictor variables at student level and at the teacher/principal level for each of the TIMSS 2007 and 2011 data from Ghana.

Hierarchical Linear Modeling Analysis

While data were collected from students, teachers (classroom), and principals (school), the sample from Ghana was such that the number of teachers was equal to the number of sampled schools. That is, there was only one teacher per school. Consequently, as indicated above, a two-level HLM was used to analyze the data where student variables were at the first level and the teacher and principal variables at the second level. Since there are no *a priori* hypotheses about between-school differences for the student predictor variables, the predictor coefficients were fixed. Only the intercepts, which correspond to the school means, were allowed to vary. Further, preliminary analyses were conducted where both the intercepts and the slopes were allowed to vary and the results indicated that the slopes of more than half of the student level variables were not significantly different from zero. Consequently, the model used was the random intercept, fixed slopes model. That is, the intercept at the student level, which was the school mean given all predictor variables were grand mean centered, varied across schools but the slopes of the predictor variables did not.

Five HLM analyses were conducted. First, the analysis of the null model, which had no predictors at the student and teacher/school levels, was conducted to obtain an estimate of the total potential explainable variance at each level. Second, the predictors at the student level were added to obtain initial estimates of the predictor coefficient for each student variable and to identify the significant predictors. Third, the same analysis was conducted at the teacher/principal level. Fourth, a full analysis was conducted with all the predictor variables entered at the student and teacher/principal levels. Fifth, a parsimonious model was conducted to remove variables from the full model in analysis four to obtain a final set of significant variables at the student level and at the teacher/principal level.

The Null or Unconditional Model

This stage of the analysis that uses the null or empty model with no predictor variables is an important step in HLM analysis because it tells us how much the variation in the outcome variable (mathematics achievement) is within or between schools. The null model addresses two fundamental necessary conditions for multilevel analyses: is there significant variance among students and among teachers/school to warrant the use of multilevel modeling analysis and, if so, how much of this variation is due to differences among students and to differences among teachers/schools?

The equations associated with the null model are:

$$Y_{ij} = \beta_{0j} + r_{ij}$$

$$\beta_{0j} = \gamma_{00} + u_{0j},$$

where $Y_{ij}$ is the mathematics achievement score of student $i$ in school j

$\beta_{0j}$ is the regression intercept of school $j$ or the mean of school $j$

$\gamma_{00}$ is the grand mean or overall average mathematics score for all schools

$r_{ij}$ is the random effect of student $i$ in school $j$, and

$u_{0j}$ is the random effect of school j, that’s the deviation of the school-mean achievement from the grand mean.

Level-1 Model (Student level)

According to Raudenbush and Bryk (2002), in HLM model building, a number of standard regression analyses are run first, starting with the theoretically important or most interesting predictor variables, and then adding predictors to the model in order of importance. The first analysis in this study was at the student level. At the student level, the outcome variable (mathematics achievement) is expressed as a function of a linear combination of all the student variables and the teacher/school model is expressed as the null model. In this step, each of the student variables was entered individually in order of importance into the null model to examine the influence of these individual variables on mathematics achievement. The aim of this analysis was to examine the influence of each of the student-level variables on mathematics achievement in the presence of other student variables.

The general linear regression equations for the student level (level-1) models were:

$$Y_{ij} = \beta_{0j} + \sum_{q=1}^{Q} \beta_{qj} X_{qij} + r_{ij}$$

$$\beta_{oj} = \gamma_{00} + u_{0j}$$

where *i, j*, and $q$ identify the students, schools, and the variable number respectively.

$Y_{ij}$, $\beta_{0j}$,and $r_{ij}$ are defined in the same way as in the empty model;

$\beta_{qj}$ are the level-1 intercepts and slopes that indicate how much of influence student level variable $X_{qij}$ has on the mathematics achievement of students within each school $j$; and

$X_{qij}$ are the 40/15 students level predictor variables.

The $r_{ij}$ term, which is the level 1 random effect or the error term, is assumed to be normally and independently distributed with a mean of zero and variance $\sigma^2$. Thus $r_{ij}$~ NID (0,$\sigma^2$).

The Teacher/ Principal Level Model

At the teacher/principal level, the level-1 intercepts or school means were used as the outcome variable to be predicted from teacher/principal level variables. Similar to the model building at the student level, the teacher/ principal level variables were included at level 2. The objective of the level 2 models was to investigate the relationship between the classroom, teacher, and school characteristics and the mean mathematics achievement of grade 8 students for the school. The regression equations were:

$$Y_{ij} = \beta_{0j} + r_{ij}$$

$$\beta_{0j} = \gamma_{q0} + \sum_{s=1}^{S_q} \gamma_{qs} W_{sj} + U_{qj}$$

In this equation, *j* denotes schools, *q* denotes level-1 parameters whiles *s* denotes level-2 parameters; $\gamma_{qs}$ denotes the level-2 coefficients; $W_{sj}$ are the 40/37 school-level variables; and $U_{qj}$ the error term at the school level. For each school j, the vector of error terms ($U_{0j}$, $U_{1j}$, $U_{2j}$, …,$U_{Qj}$ ) are assumed to be multivariate normally and independently distributed such that each $U_{qj}$ has a mean of zero and variance $\tau_{qq}$ .

The Combined Equation (Full Model)

Combining equations at the students' model and teacher/principal model resulted in the equation for the full model given below:

$$Y_{ij} = \beta_{0j} + \sum_{q=1}^{Q} \beta_{qj} X_{qij} + r_{ij}$$

$$\beta_{0j} = \gamma_{q0} + \sum_{s=1}^{S_q} \gamma_{qs} W_{sj} + U_{qj}$$

The full sets of student and teacher/principal variables are included in the full model

Parsimonious Model

The parsimonious model was the final model that was constructed for this analysis. A back and forth approach was taken to remove first the weakest predictors across the two levels, then the weakest was brought back into the model and the second weakest across the two levels was removed. If the weakest was still not significant, then both variables were removed. The procedure continued in this manner until there were no non-significant predictors at each level. This resulted in a model that contained only significant predictors at each level. The HLM 7 statistical program (Raudenbush et al., 2011) was used to perform the analyses of the TIMSS 2007 and 2011 datasets. The data analysis typically involved three stages: (a) construction of the multivariate data matrix (MDM) file; (b) performing the analyses based on the MDM file; and (c) evaluation of the fitted models using the results and the residual file.

To answer research question 1, the statistical results from the analyses of the parsimonious model were used to make inference about which of the student and teacher/principal variables combined best to predict the mathematics achievement of Grade 8 students on TIMSS 2007 at Level 1 and the school means at Level 2. In the case of research question 2, the same results from the analysis of the parsimonious model for the 2011 dataset was used.

By visually examining the strength of association between the student level variables and the mathematics achievement across 2007 and 2011; and also examining the strength of association between school and classroom characteristics and mathematics achievement across 2007 and 2011, research questions 3 and 4 were addressed.

As stated above, the lists of all the variables that were considered in 2007 and 2011 are presented, respectively, in Tables 6 and 7 below. Detailed information about all the variables are provided in Appendix A.

**Summary**

This chapter highlighted the methodology that was employed in the present study. First, the TIMSS research design, including the data, the sample for the study, the achievement instrument, and the background questionnaires from which variables were selected for the present study, was reviewed. The issue of missing data and its treatment and the application of appropriate sampling weights during the analysis were then addressed. The use of Exploratory Factor Analysis (EFA) to reduce the number of variables was described, followed by presentation of the results of the EFA, which revealed that both the 12 attitude items used in 2007 student questionnaire and 19 attitude items used in the student questionnaire in 2011 loaded on three-factors: self-confidence in mathematics, value of mathematics, and perceived difficulty of mathematics. Lastly, the HLM analysis and the equations associated with the respective levels of the analysis were presented.

Table 6: *Student-, Teacher-, and Principal-level Variables for 2007*

| Student Variables | Teacher and Principal Variables |
|---|---|
| | *Teacher Variables* |
| Gender | Teacher's gender |
| Testing language at home | Teachers' qualification |
| Father's educational level | Teaching experience |
| Mother's educational level | Six Teacher's major of study |
| Number of books | Teacher's certification |
| Amount of homework | Ready to teach number |
| Time spent on homework | Ready to teach Algebra |
| Educational aspiration | Ready to teach Geometry |
| Self-confidence in learning mathematics. | Ready to teach Data and Chance |
| Students' valuing mathematics | Teacher beliefs |
| Perceived difficulty | Mathematics-related professional development |
| Home possessions | Teacher's Instructional practices |
| Students' feeling of safety in the school | Teachers' Perception of School Climate |
| 17 Instructional practices | Mathematics teachers' perception of school facility and safety |
| Student perception of the school | Limiting mathematics instruction due to student factors |
| Nine Out-of-school activities | Opportunity to learn number |

Table 6 (Cont.)

| Student Variables | Teacher and Principal Variables |
|---|---|
| | *Teacher Variables* |
| | Opportunity to learn algebra |
| | Opportunity to learn geometry |
| | Opportunity to learn data and chance |
| | Amount of homework |
| | Monitoring students' progress |
| | Item formats |
| | Four Question types |
| | *Principal Variables* |
| | School location |
| | Class size |
| | Principal's perception of school climate |
| | Expected parental involvement |
| | Evaluation of mathematics teachers |
| | Availability of school resources for mathematics instruction |

Table 7: *Student-, Teacher-, and Principal-level Variables for 2011*

| Student Variables | Teacher and Principal Variables |
|---|---|
| | *Teacher Variables* |
| Gender | Teacher's gender |
| Testing language at home | Teachers' qualification |
| Father's educational level | Teaching experience |
| Mother's educational level | Six Teacher's major of study |
| Number of books | Ready to teach number |
| Amount of homework | Ready to teach Algebra |
| Time spent on homework | Ready to teach Geometry |
| Educational aspiration | Ready to teach Data and Chance |
| Self-confidence in learning mathematics. | Teacher beliefs |
| Students' valuing mathematics | Mathematics-related professional development |
| Perceived difficulty | Teacher's Instructional practices |
| Home possessions | Teachers' Perception of School Climate |
| Students' feeling of safety in the school | Mathematics teachers' perception of school facility and safety |
| Home support | Limiting mathematics instruction due to student factors |
| Student perception of the school | Opportunity to learn number |

Table 7 (Cont.)

| Student Variables | Teacher and Principal Variables |
|---|---|
| | *Teacher Variables* |
| | Opportunity to learn algebra |
| | Opportunity to learn geometry |
| | Opportunity to learn data and chance |
| | Amount of homework |
| | Monitoring students' progress |
| | Item formats |
| | Four Question types |
| | *Principal Variables* |
| | School location |
| | Class size |
| | Principal's perception of school climate |
| | Expected parental involvement |
| | Evaluation of mathematics teachers |
| | Availability of school resources for mathematics instruction |

# CHAPTER 4: RESULTS OF TIMSS 2007

The results of the analyses for the TIMSS 2007 data are presented in this chapter and the results of the analyses for the TIMSS 2011 data are presented in the next chapter. This chapter is organized in two sections. In the first section, the descriptive statistics for the five plausible values are presented. The second section contains the results for the HLM analyses.

**Descriptive Statistics**

After using the expectation maximization (EM) method to replace the missing values, the final sample for 2007 consisted of 5,235 students nested within 162 schools. The class sizes ranged from 8 to 143 students and the mean class size was 43.

The minimum value, maximum value, mean, and standard deviation of the five plausible values for the TIMMS 2007 are reported in Table 8. As shown in Table 9, the minimum standard scores are closer in value than the maximum plausible standard scores (5.00 to 5.16 vs. 599.14 to 637.49). This shows that there are no outliers in the distribution of scores obtained by the Ghana's grade eight students in all the five plausible values in TIMSS 2007. The means and standard deviations of the five plausible values are also quite close together (316.74 to 318.86 and 90.10 to 91.97, respectively), and they provide an unbiased estimates of the means and standard deviations for the Ghanaian population.

Table 8: *Descriptive Statistics for Five Plausible Values TIMSS 2007 N = 5235*

| Plausible Values | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|
| 1ST | 5.00 | 599.14 | 318.08 | 90.10 |
| 2ND | 5.16 | 622.12 | 16.74 | 91.97 |
| 3RD | 5.00 | 637.49 | 16.14 | 93.23 |
| 4TH | 5.00 | 624.03 | 316.90 | 91.31 |
| 5TH | 5.00 | 634.98 | 318.86 | 91.35 |

Figure 2 presents the frequency polygon for the first plausible value. The graphs for the other four plausible values are similar in shape. The graph is essentially normal in shape as seen by the fitted line graph. The graph reveals that approximately 42% of the students in 2007 scored lower than two standard deviations below the mean and that no students in 2007 scored above 1.25 standard deviations above the mean. The large percentage of low scores led to the mean being just above two standard deviations below the mean.

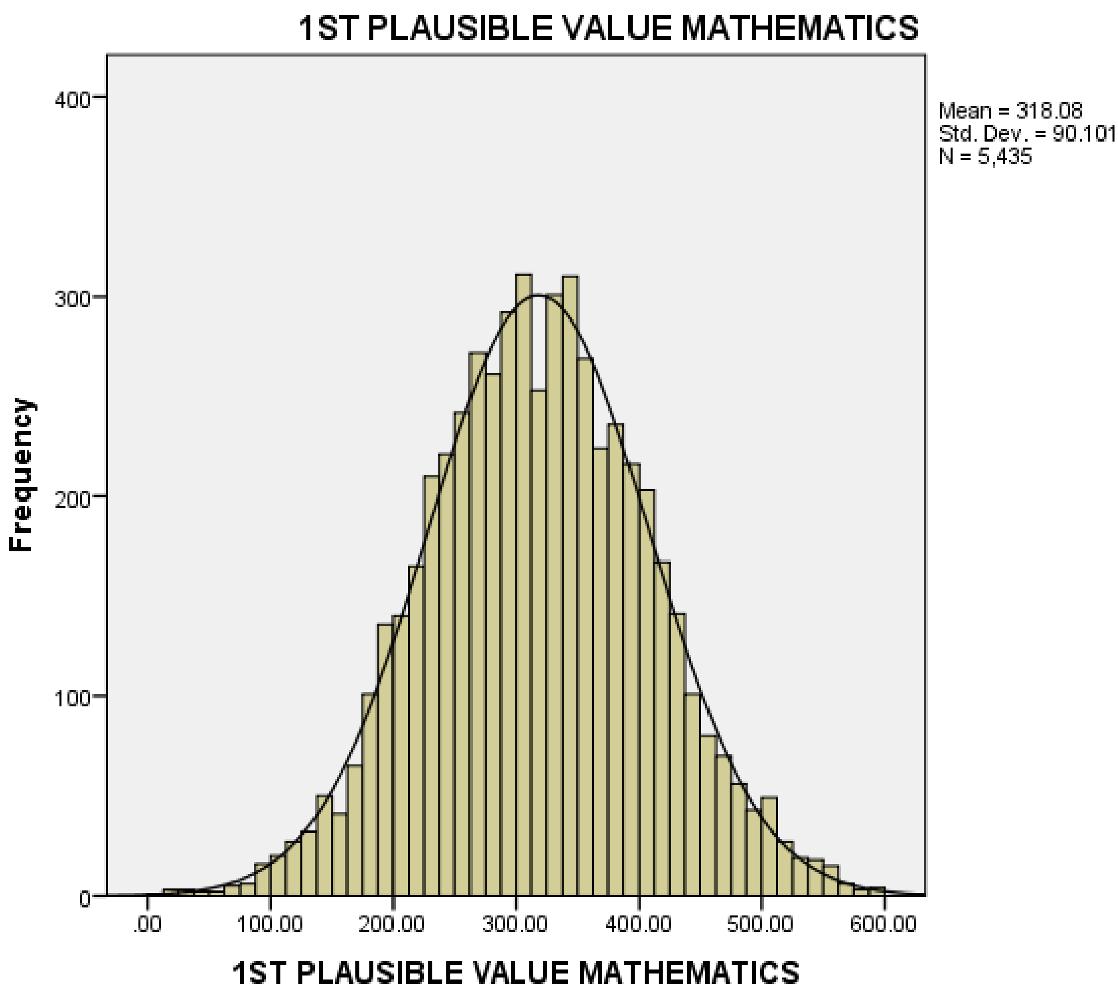


*Figure* 2: Frequency polygon for first plausible value in mathematics

**Hierarchical Linear Modeling and Results**

As described in Table 6 in Chapter Three, there were 40 student predictor variables at Level 1 and 40 teacher and principal predictor variables at Level 2 in 2007. A detailed description of each predictor variable is provided in Appendix A and the descriptive statistics for all of the variables are presented in Table 1 Appendix B.

Five HLM analyses were conducted. First, the analysis of the null model, which has no predictors at the student and teacher/principal levels, was conducted to obtain an estimate of the total explainable variance at each level. Second, the predictors at the student level were added to obtain initial estimates of the predictor coefficients of the 40 student variables in the absence of teacher and principal variables and to identify the significant predictors. Third, the student variables were removed and the teacher and principal variables were added at Level 2 to obtain initial estimates of the predictor variables for the teacher and principal variables in the absence of the student variables. Fourth, a full analysis was conducted with all of the predictor variables entered at the student and teacher/school levels. Fifth, a parsimonious model was conducted to remove and/or add variables from the full model in analysis four to obtain a final set of significant variables at the student level and at the teacher/principal level.

All the variables used in this analysis were grand-mean centered. Centering in hierarchical linear modeling is important because it facilitates the interpretation of the intercept and makes it meaningful. When the explanatory variables are grand-mean centered, the intercept is equal to the school mean for student performance at Level 1 and the grand mean for student performance at Level 2 (Hox, 1995; Raudenbush, & Bryk, 2002;Snijders, & Bosker, 1999).

*The Null Model*

The null model is the unconditional model with no predictor variables at both levels. The null model addresses two fundamental and necessary conditions for multilevel analyses: is there significant variance among students and among teachers/principals to warrant the use of multilevel modeling analysis and, if so, how much of this variation is due to differences among students and to differences among teachers/schools?

The results of the null model are reported in Table 9. The variance at the student level is 4957.08, which represents 59.4% of the total variance. The variance at the teacher/principal level is 3379.90, which represents 40.6% of the total variance. Further, the variance at the teacher/principal level is significantly different from zero.

Table 9: *Summary Results for the Null Model*

| *Random Effect* | *Variance Component* | *Standard Deviation* | *df* | *Chi-square* | *p-value* |
|---|---|---|---|---|---|
| $\tau_{00}$ | 3379.90 | 58.14 | 161 | 3987.13 | 0.000 |
| $\sigma^2$ | 4957.08 | 70.41 | | | |

The results of the null model also include an estimate of how reliable the estimates of the school sample means are. The average reliability of school means for 2007 was 0.95, which indicated that the sample means were highly reliable as indicators of the true school means.

*Student Model (Level 1)*

The student model, which is also known as the Level 1 or random-intercept model, is a model where only student-level variables were added to the student-level equation of the null model. The 40 student variables listed in Table 6 (in Chapter 3) were considered. The results for all 40 variables are reported in Table 2, Appendix B. As shown in this table, the coefficients for half of the items were significantly different from zero. Given the same 20 student variables were significant in the full model and the parsimonious model, the 20 significant student's predictor variables are discussed below under the parsimonious model.

*Teacher/Principal Model (Level 2)*

In this model, which is also known as intercepts as outcome model, the 40 teacher/principal level variables were added to the teacher/principal equation of the null model, while the student model had no predictors. The 40 teacher/principal variables included in the model are listed in Table 8 in Chapter Three. The results for all 40 variables are reported in Table 3, Appendix B. As shown in this table, the coefficients for six of the variables were significantly different from zero. Further, unlike the student level variables, the number of significant teacher/principal variables was not constant across the Level 2, full, and parsimonious models. Therefore, significant teacher/principal predictor variables are discussed in the text for each of the models.

The results for the intercepts as outcome model indicated that Grade 8 students that were taught by teachers who took mathematics education as the major field of study tended to have higher scores in the mathematics achievement than Grade 8 students taught by teachers who did not take mathematics as a major field of study. In contrast, teacher certification had an inverse relation. Students taught by uncertified teachers scored higher than students taught by certified teachers.

Students who attended classes with teachers who felt safe in school scored higher than students who attended classes with teachers who did not feel safe in school. Amount of homework completed by students was positively related to performance; students who completed more homework outperformed students who completed less homework. Interestingly class size was positively related to student performance; students in larger classes outperformed students in smaller size classes. Lastly, students in schools in which the principals held a positive perception of their school outperformed students in schools in which the principals held a less positive perception of their schools.

After adding 40 teacher/principal variables into the Level 2 equation, the estimated between-school variance ($\tau_{00}$) dropped to 1825.73. Comparing this variance to the estimated between-school variance in the null model indicated that the proportion reduction in variance in the Level-2 model compared with the null model was (3379.90 – 1825.73) / 3379.90 = 46.0%. This implied that the school-level variables accounted for about 46.0% of the school-level variance in students' mathematics achievement. Clearly not all the variance among schools was accounted for by the teacher/principal variables included in this study.

*The Full Model*

The full model or random-intercept model with nonrandomly varying slopes included the full set of student, teacher, and principal variables included at Level 1 and Level 2. The purpose of the full model analysis was to identify the significant variables at each level of the analysis taking into consideration the relationship among these variables both within and across the two levels. Since in this study, there were no a prior hypotheses about the interaction between predictor variables at each level, the interaction effects between the variables were not tested.

The coefficients and their significance levels for all 40 student variables and all 40 teacher/principal variables for the full model are provided in Table 4 Appendix B. As indicated earlier, the results for the full model indicated that whereas the same 20 significant predictors of mathematics achievement for the student level model were significant for the full and parsimonious models, the significant teacher/principal variables were not consistent across models. Four of the six significant teacher/principal variables at Level 2 were significant for the full model at Level 2, and no teacher/principal variables were added. The four significant teacher/principals variables were teacher certification (negatively related), class size, amount of homework given to students, and principal's perception of the school (positively related). These results indicated that teacher certification had an inverse relation. Students taught by uncertified teachers scored higher than students taught by certified teachers. Amount of homework completed by students was positively related to performance; students who completed more homework outperformed students who completed less homework. Interestingly class size was positively related to student performance; students in larger classes outperformed students in smaller size classes. Lastly, students in schools in which the principals held a positive perception of their school outperformed students in schools in which the principals held a less positive perception of their schools.

*The Parsimonious Model*

An iterative procedure was employed to obtain the parsimonious model from the full model. First the least significant predictor across the two levels was removed from the full model, and then brought back into the model at the same time the second least predictor was removed from the model. This back and forth procedure continued until only significant predictors are remained at each level. The results are provided in Table 10.

Twenty student variables were significant in the student, full, and parsimonious models. For the teacher/principal level, six variables were significant for the teacher/principal model, four of the six were significant for the full model and two of the four variables – teacher licensure and principals' perceptions of their schools – and two additional teacher/principal variables –

mathematics education and teachers' instructional practices – were significant for the parsimonious model.

The results from the parsimonious model for 2007 were used to answer research question 1: What combination of student-level and school-level characteristics best explained students' mathematics achievement in Ghana in TIMSS 2007? The student level results are discussed first, followed by the teacher/principal results and the variance explained at each level.

*Student level*. As shown in the upper panel of Table 10, the coefficient for gender was 15.71, which indicated that boys tended to perform better than girls on the TIMSS 2007 mathematics test. Students having higher educational aspirations (b = 4.08) tended to have higher scores on the mathematics test than students with lower educational aspirations. Likewise, students with high self-confidence in mathematics and placed high value on mathematics (b = 13.23 and b = 7.58) tended to outperform students with low self-confidence in mathematics and place low value on mathematics.

Six of the 17 instructional variables were significantly related to performance. One of the instructional variables – *we practice adding, subtracting, multiplying, and dividing without using a calculator* – had a positive association (b = 5.60) with mathematics achievement. The remaining five variables - *solve problems about geometric shapes* (b = -5.15)*, decide on our own*

Table 10: *Significant Predictors of the Parsimonious Model*

| | *B* | *S.E* | *t-ratio* | *p-value* |
|---|---|---|---|---|
| **Student Variables** | | | | |
| Students' gender | 15.71 | 2.73 | 5.76 | 0.000 |
| Level of aspiration | 4.08 | 0.73 | 5.59 | 0.000 |
| Self-confidence in mathematics | 13.23 | 1.59 | 8.31 | 0.000 |
| Value of mathematics | 7.58 | 2.18 | 3.48 | 0.005 |
| Practice adding, subtracting, multiplying, and dividing without using a calculator | 5.60 | 1.27 | 4.42 | 0.001 |
| Solve geometric problem | -5.15 | 1.51 | -3.41 | 0.003 |
| Use calculators | -5.48 | 1.86 | -2.94 | 0.007 |
| Use computers | -7.43 | 1.66 | -4.45 | 0.000 |
| Decide procedures for complex problems | -3.46 | 1.12 | -3.01 | 0.003 |
| Students perception of the school | 5.53 | 1.97 | 2.80 | 0.017 |
| Students safety in school | -2.46 | 1.11 | -2.22 | 0.028 |
| Perceived difficulty of mathematics | -11.89 | 2.17 | -5.48 | 0.001 |
| Begin homework in class | -8.19 | 1.60 | -5.11 | 0.000 |
| I do my homework | 3.52 | 1.36 | 2.61 | 0.025 |
| Time spent on homework | 4.33 | 1.16 | 3.73 | 0.003 |
| Number of books at home | -2.46 | 1.03 | -2.40 | 0.018 |
| Home possessions | -4.54 | 1.65 | -2.75 | 0.013 |
| I work at paid jobs | -2.63 | 1.11 | -2.37 | 0.023 |
| I read book for enjoyment | 2.95 | 0.96 | 3.05 | 0.003 |
| I use the internet | -8.01 | 1.27 | -6.31 | 0.000 |
| **Classroom/Teacher/School level variables** | | | | |
| Teaching license or certificate | -23.90 | 8.52 | -2.80 | 0.006 |
| Education- Mathematics | 15.45 | 7.36 | 2.10 | 0.037 |
| Amount of homework | 9.90 | 3.90 | 2.54 | 0.012 |
| Teachers' instructional practices | 2.59 | 1.09 | 2.38 | 0.018 |
| Principal perception of the school | 3.09 | 0.73 | 4.24 | 0.00 |

*procedures for solving complex problems* (b = -3.46), *begin our homework in class* (b = -8.19), *we use calculators* (b = -5.48), and *we use computers (*b = -7.43) – were negatively related to mathematics achievement.

Students who held positive perceptions of their school tended to have higher achievement in mathematics than students with low perceptions of their schools (b = 5.53). In contrast, students who felt and said they were hurt by other students, bullied, and had things stolen while in school tended to have lower scores in the mathematics achievement than students who felt safe in school (b = -2.46). Students who stated that mathematics was boring, difficult, and not one of their strengths tended to obtain lower scores than students who were not bored, did not find mathematics difficult, and saw mathematics as one of their strengths (b = -11.89).

Students who spent more time on their homework tended to have higher achievement in mathematics than students who spent less time on their homework (b = 4.33). Similarly students who spent more time outside of the school doing mathematics homework outperformed the students who spent less time outside of the school doing mathematics homework (b = 3.52).

The numbers of books in a student's home and home possessions were both negatively related to mathematics performance. This indicated that students having more books at home and living in a home with more home possessions tended to obtain lower mathematics scores than students with fewer books at home and living in a home with fewer home possessions (b = -2.46 and b = -4.54, respectively).

Students who spent more time outside of school working at paid jobs or surfing the Internet tended to perform less well than students who did not work at paid jobs or surf the internet (b = -2.63 and -8.01, respectively). In contrast reading books for enjoyment was positively related to mathematics performance. (b = 2.95).

*Teacher/principal level*. The results shown in the lower panel of Table 10 reveal that students taught by teachers with a teaching license/certificate performed less well than students taught by teachers without a teaching license/certificate (b = -23.90). In contrast, students taught by a teacher with a mathematics education major outperformed students taught by teachers without a mathematics education major (b = 15.45). Students whose teachers frequently assigned homework tended to obtain higher scores on the mathematics test than students whose teachers infrequently assigned homework (b = 9.90). Lastly, students with teachers who had strong instructional practices tended to perform at a higher level on the mathematics test than students with teachers who did not employ strong instructional practice (b = 2.59). Lastly and as before with the teacher/principal and full models, principals' perceptions of their schools was positively related to mathematics achievement (b = 3.09)

*Proportion of variance explained*. The proportions of variance in the mathematics achievement scores explained by the significant predictors at both levels are displayed in Table 11. As shown, the 20 significant student predictors explained 27.3% of the variance of mathematics achievement at the student level. The five significant teacher/principal level predictors explained 54.7% of the variance in the mathematics achievement at the teacher/classroom level. The finding that just over a quarter of the student variance was explained suggests that additional variables need to be included to better explain the student variance. The finding that slightly more than half of the variance was explained at Level 2 suggests that although Ghana follows a centralized education system, the schools appear not to be homogenous when it comes to instruction in mathematics and the possible need for additional variables at the teacher/principal level to the test

Table 11: *Proportion of Variance Explained at Student and School Level*

| Level | Initial Variance | Final Variance | Percent Variance Explained |
|---|---|---|---|
| Student | 4957.08 | 3610.25 | 27.3% |
| Teacher/principal | 3379.90 | 1531.66 | 54.7% |

**Summary**

The results of the HLM analyses of the TIMSS 2007 data revealed that 20 student-level variables were significantly related to mathematics achievement in Ghana. The effects of some of these student-level variables were positive (e.g., gender, educational aspiration, self-confidence, and value for mathematics), and others were negative (e.g., perceived difficulty, students' safety at school, begin homework in class, and I use internet). Five teacher/principal variables were significantly related to Ghana's grade eight students' mathematics achievement in TIMSS 2007. Interestingly, whereas the effects of Mathematics education major, amount of homework, teacher's instructional practices, and principals' perception of the climate were positive, the effect of teaching license was negative; suggesting that possession of a teaching license is negatively associated with mathematics achievement.

# CHAPTER 5: RESULTS OF TIMSS 2011

The results of the analyses for the TIMSS 2011 data are presented in this chapter. The chapter is organized in two sections. In the first section, the descriptive statistics for the five plausible values are presented. The second section contains the results for the HLM analyses.

## Descriptive Statistics

After using the expectation maximization (EM) method to replace the missing values, the final sample for 2011 consisted of 7,304 students nested within 160 schools. The class sizes ranged from 10 to 242 students and the mean class size was 48.00 students per class.

The minimum value, maximum value, mean, and standard deviation of the five plausible values for the TIMSS 2011 are reported in Table 12. As shown in Table 12, the minimum standard plausible scores range are closer in value than the maximum plausible standard scores (39.00 to 65.89 vs. 655.73 to 729.66). This shows that there are no outliers in the distribution of scores obtained by the Ghana's grade eight students in all the five plausible values in TIMSS 2011. The means and standard deviations of the five plausible values are also quite close together (332.38 to 335.90 and 85.22 to 86.67, respectively), and they provide an unbiased estimates of the means and standard deviations for the Ghanaian population.

Table 12: *Descriptive Statistics for Five Plausible Values TIMSS 2011 N = 7304*

| Plausible Values | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|
| 1ST | 54.42 | 655.73 | 335.90 | 85.22 |
| 2ND | 55.89 | 688.21 | 334.60 | 85.95 |
| 3RD | 57.38 | 710.21 | 332.38 | 86.67 |
| 4TH | 39.00 | 660.22 | 332.50 | 86.38 |
| 5TH | 50.16 | 729.66 | 334.01 | 85.89 |

Figure 3 presents the frequency polygon for the first plausible value. The graphs for the other four plausible values are similar in shape. The graph is essentially normal in shape as seen by the fitted line graph. The graph reveals that approximately 35% of the students in 2011 scored lower than two standard deviations below the mean and that only four students in 2011 scored above 1.25 standard deviations above the mean. The large percentage of low scores led to the mean being just above two standard deviations below the mean.

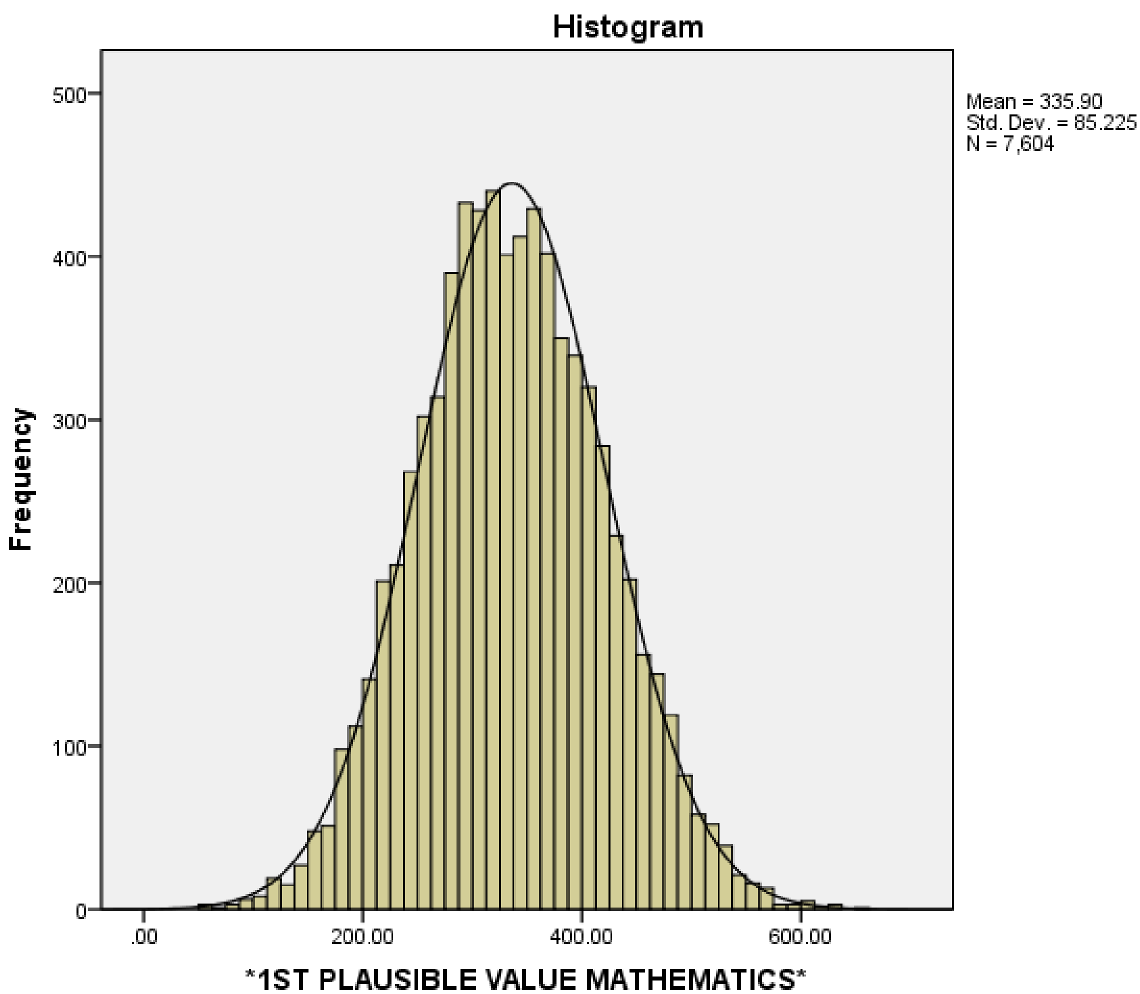


*Figure 3*: Frequency polygon for first plausible value in mathematics

**Hierarchical Linear Modeling and Results**

There were 15 student predictor variables at Level 1 and 37 teacher and principal predictor variables at Level 2 in 2011, as described in Table 7 in Chapter 3. These numbers are smaller than the numbers for 2007, particularly at the student level (15 vs. 40 and 37 vs. 40). The reason for the difference between the numbers of students and teacher/principal variables in 2007 and 2011 is due to changes in the student, teacher, and principal questionnaires. A detailed description of each predictor variable is provided in Appendix A and the descriptive statistics for all of the variables are presented in Table 1 Appendix C.

Five HLM analyses were conducted. First, the analysis of the null model was conducted to obtain an estimate of the total explainable variance at each level. Second, the predictors at the student level were added to obtain initial estimates of the predictor coefficients of the 15 student variables in the absence of teacher and principal variables and to identify the significant predictors. Third, the student variables were removed and the teacher and principal variables were added at Level 2 to obtain initial estimates of the predictor variables for the teacher and principal variables in the absence of the student variables. Fourth, a full analysis was conducted with all of the predictor variables entered at the student and teacher/school levels. Fifth, a parsimonious model was conducted to remove and/or add variables from the full model in analysis four to obtain a final set of significant variables at the student level and at the teacher/principal level.

All the variables used in this analysis were grand-mean centered so that the intercept is equal to the school mean for student performance at Level 1 and the grand mean for student performance at Level 2 (Hox, 1995; Raudenbush, & Bryk, 2002;Snijders, & Bosker, 1999).

*The Null Model*

The null model is the unconditional model with no predictor variables at both levels. The null model addresses two fundamental and necessary conditions for multilevel analyses: is there significant variance among students and among teachers/principals to warrant the use of multilevel modeling analysis and, if so, how much of this variation is due to differences among students and to differences among teachers/schools?

The results of the null model are reported in Table 13. The variance at the student level is 4347.01, which represents 59.8% of the total variance. The variance at the teacher/principal level is 2927.94, which represents 40.2% of the total variance. Further, the variance at the teacher/principal level is significantly different from zero.

Table 13: *Summary Results for the Null Model*

| *Random Effect* | *Variance Component* | *Standard Deviation* | *df* | *Chi-square* | *p-value* |
|---|---|---|---|---|---|
| $\boldsymbol{\tau_{00}}$ | 2927.94 | 54.11 | 159 | 5340.10 | 0.000 |
| $\boldsymbol{\sigma^2}$ | 4347.01 | 65.93 | | | |

The results of the null model also include an estimate of how reliable the estimates of the school sample means are. The average reliability of school means for 2011 was 0.97, which indicates that the sample means are highly reliable as indicators of the true school means.

*Student Model (Level 1)*

The student model, which is also known as the Level 1 or random-intercept model, is a model where only student-level variables were added to the student-level equation of the null model. The 15 student variables listed in Table 7, Chapter 3, were considered. The results for all

15 variables are reported in Table 2, Appendix C. As shown in Table 2 Appendix C, the coefficients for 10 of the variables were significantly different from zero. The results indicated that the 10 significant student variables were also significant in the full model and nine out of the 10 were significant at the parsimonious model. The nine significant student's predictor variables are discussed below under the parsimonious model. The results show that mothers' educational level was a significant predictor of mathematics achievement in both the students' and full models. In the students' model, mothers' educational level was negatively related (b = -1.58) to mathematics achievement meaning that students with highly educated mothers tended to have lower scores on the mathematics achievement than students with less educated mothers.

*Teacher/Principal Model (Level 2)*

In this model, which is also known as intercepts as outcome model, the 37 teacher/principal level variables were added to the teacher/principal equation of the null model, while the student model had no predictors. The 37 teacher/principal variables included in the model are listed in Table 7 in Chapter Three. The results for all 37 variables are reported in Table 3, Appendix C. As shown in Table 3 Appendix C, the coefficients for five of the variables were significantly different from zero. Further, unlike the student level variables, the five significant teacher/principal variables were also significant across the Level 2, full, and parsimonious models. However, as will be seen below, an additional teacher/principal variable was added in the full model and retained in the parsimonious model, and a second teacher/principal variable was added in the parsimonious model. Significant teacher/principal predictor variables are discussed below under the parsimonious model.

After adding 37 teacher/principal variables into the Level 2 equation, the estimated between-school variance ($\tau_{00}$) dropped to 1579.34. Comparing this variance to the estimated between-school variance in the null model indicated that the proportion reduction in variance in the Level-2 model compared with the null model was (2927.94 – 1579.34) / 2927.94 = 46.1%. This implied that the school-level variables accounted for about 46.1% of the school-level variance in students' mathematics achievement.

*The Full Model*

The full model or random-intercept model with nonrandomly varying slopes includes the full set of student, teacher, and principal variables included at Level 1 and Level 2. The purpose of the full model analysis was to identify the significant variables at each level of the analysis taking into consideration the relationship among these variables both within and across the two levels. Since in this study, there were no a priori hypotheses about the interaction between predictor variables at each level, the interaction effects between the variables were not tested.

The coefficients and their significance levels for all 15 student variables and all 37 teacher/principal variables for the full model are provided in Table 4 Appendix C. The results for the full model indicated that the same 10 significant predictors of mathematics achievement for the student level model were significant for the full model. The results of the full model also indicated that in addition to the five significant teacher/principal variables, teachers' perception of the school was positively related to mathematics achievement.

*The Parsimonious Model*

An iterative procedure was employed to obtain the parsimonious model from the full model. First the least significant predictor across the two levels was removed from the full model, and then brought back into the model at the same time the second least predictor was removed from the model. This back and forth procedure continued until only significant predictors are remained at each level. The results are provided in Table 14.

As indicated above, the same 10 student variables were significant in the student, full, and nine out of the 10 in the parsimonious models. For the teacher/principal level, five variables were significant for the teacher/principal model, the same five and teachers' perception of the school were significant for the full model, and the same five variables and two additional variables – teachers' perceptions of their schools, and science education were significant for the parsimonious model.

The results from the parsimonious model for 2011 were used to answer research question 2: What combination of student-level and school-level characteristics best explained students' mathematics achievement in Ghana in TIMSS 2011? The student level results are discussed first, followed by the teacher/principal results and the variance explained at each level.

*Student level*. As shown in the upper panel of Table 14 above, the coefficient for gender was 18.46, which indicated that boys tended to perform better than girls on the TIMSS 2011 mathematics test. Students having higher educational aspirations (b = 7.33) tended to have higher scores on the mathematics test than students with lower educational aspirations. Likewise, students with high self-confidence in mathematics and placed high value on mathematics (b = 8.50 and b = 10.71) tended to outperform students with low self-confidence in mathematics and place low value on mathematics.

Table 14: *Significant Predictors of the Parsimonious Model*

| | *B* | *S.E* | *t-ratio* | *p-value* |
|---|---|---|---|---|
| **Student Level Variables** | | | | |
| Students' gender | 18.46 | 2.09 | 8.84 | 0.000 |
| Level of aspiration | 7.33 | 1.19 | 6.15 | 0.001 |
| Self-confidence in mathematics | 8.50 | 1.02 | 8.34 | 0.000 |
| Value of mathematics | 10.71 | 1.42 | 7.55 | 0.000 |
| Students perception of the school | 4.99 | 1.45 | 3.43 | 0.007 |
| Students safety in school | -4.48 | 1.26 | -3.55 | 0.006 |
| Perceive difficulty of mathematics | -16.48 | 1.10 | -14.92 | 0.000 |
| Frequency of homework | 3.35 | 1.23 | 2.72 | 0.019 |
| Time spent on homework | 3.37 | 1.11 | 3.04 | 0.016 |
| **Classroom/Teacher/School level variables** | | | | |
| Mathematics Major | 28.80 | 7.40 | 3.89 | 0.000 |
| Science Major | -11.26 | 3.26 | -3.45 | 0.001 |
| Science Education Major | 23.27 | 7.16 | 3.25 | 0.001 |
| Class Test | 18.75 | 7.43 | 2.53 | 0.013 |
| Recall Questions | -16.07 | 5.86 | -2.74 | 0.007 |
| School location | 10.60 | 2.59 | 4.09 | 0.000 |
| Teachers' perception of the school | 2.84 | 0.72 | 3.95 | 0.000 |

Students who held positive perceptions of their school tended to have higher achievement in mathematics than students with low perceptions of their schools (b = 4.99). In contrast, students who felt and said they were hurt by other students, bullied, and had things stolen while in school tended to have lower scores in the mathematics achievement than students who felt safe in school (b = -4.48). Students who stated that mathematics was boring, difficult, and not one of their strengths tended to obtain lower scores than students who were not bored, did not find mathematics difficult, and saw mathematics as one of their strengths (b = -16.48).

Students who were frequently assigned mathematics homework tended to have higher achievement in mathematics than students who were infrequently assigned mathematics homework (b = 3.35). Similarly students who spent more time on their mathematics homework outperformed the students who spent less time on their mathematics homework (b = 3.37).

*Teacher/principal level*. The results shown in the lower panel of Table 14 reveal that student taught by teachers with a mathematics major or science education major outperformed students taught by teachers without mathematics or science education majors (b = 28.80 and b = 23.27). In contrast, students taught by a teacher with a science major performed less well than students taught by teachers without a science major (b = -11.26). Students whose teachers placed much emphasis on class tests as a means of monitoring students' progress tended to outperform students whose teachers placed less emphasis on class tests (b = 18.75). In contrast, students whose teachers frequently used questions based on recall of facts and procedures tended to perform less well than students whose teachers infrequently used recall questions (b = -16.07). Students in larger communities tended to perform well than students in smaller communities (b = 10.60). Lastly, teachers perceptions of their schools was positively related to mathematics achievement (b = 2.84)

*Proportion of variance explained*. The proportions of variance in the mathematics achievement scores explained by the significant predictors at both levels are displayed in Table 15. As shown, the nine significant student predictors explained 20.0% of the variance of mathematics achievement at the student level. The seven significant teacher/principal level predictors explained 54.1% of the variance in the mathematics achievement at the teacher/classroom level. The finding that less than a quarter of the student variance was explained suggests that additional variables need to be asked to better explain the student variance. The finding that slightly more than half of the variance was explained at Level 2 suggests that although Ghana follows a centralized education system, the schools appear not to be homogenous when it comes to instruction in mathematics and the possible need for additional variables to the teacher/principal questionnaire.

Table 15: *Proportion of Variance Explained at Student and School Levels*

| Level | Initial Variance | Final Variance | Percent Variance Explained |
|---|---|---|---|
| Student | 4347.01 | 3475.58 | 20.0% |
| Teacher/principal | 2927.94 | 1342.95 | 54.1% |

**Summary**

The results of the analysis of the TIMSS 2011 data revealed that the effects of nine student-level variables were significantly related to mathematics achievement in Ghana. The effects of some of these student-level variables were positive (gender, educational aspiration, self-confidence, value for mathematics, students perception of the school, frequency of homework, and time spent on homework) and others were negative ( perceived difficulty, and students' safety at school). Seven teacher/principal variables were significantly related to Ghana's grade eight students' mathematics achievement in TIMSS 2011.  The effect of mathematics major, science education major, the use of class test, teachers' perception of the school climate, and the school's location were positively associated with mathematics achievement, whereas the effects of science major and use of recall questions were negatively related to mathematics achievement.

# CHAPTER 6: DISCUSSION

This chapter is divided into seven sections. The first section provides an overview of the current study, the research questions, and a summary of the methods employed to address the research questions. The summary of results for 2007 and the summary of the results for 2011 are provided in Section 2. Section 3 provides the discussion of the results of the current study in terms of the literature reviewed. The limitations of the present study are presented in Section 4. The conclusions are contained in Section 5. Implications for practice and the recommendations for future research are provided in the last two sections. .

## Research Purpose and Methods

The purpose of this study was to investigate which factors measured in the student, teacher, and principal questionnaires administered as part of TIMSS 2007 and 2011 predicted the performance of Ghanaian grade 8 students on the TIMSS 2007 and 2011, respectively. Specifically, the present study was aimed at identifying which student and teacher/principal variables combined best to explain grade 8 students' mathematics achievement in TIMSS 2007 and 2011, and to also find out if the association between these variables and mathematics achievement was similar across the two years. The 'Input-Process-Output' model (Rumberger & Palardy, 2004; Shavelson, McDonnell, Oakes, Carey, & Picus, 1987) that models the schooling process as a cluster system where students' learning achievement is influenced by students' background variables, teacher/classroom characteristics, and school characteristics and the findings from the review of related literature were used as guides to select the variables for this study.

This study is a secondary data analysis study in which the data for mathematics was collected by the Trends in International Mathematics and Science Study in 2007 and 2011. Given a matrix sampling design was used to collect the data, the dependent variable, which was overall mathematics achievement for each student, was indicated by a set of five plausible values. Given the presence of missing data at the student, teacher/ principal levels, the maximum likelihood with expectation maximization (EM) algorithms was employed to replace all the missing values at both the student level and teacher/principal level for both 2007 and 2011. This resulted in a final sample of 5,235 students nested in 162 schools in 2007, and 7,304 students nested in 160 schools in 2011. Prior to selecting the independent variables to be considered, exploratory factor analyses were conducted for the sets of attitude items included in the 2007 and 2011 student questionnaire. The results revealed three factors for the 12 attitude items used in 2007 and the 19 attitude items used in 2011. The three factors were labeled self-confidence, value of mathematics, and perceived difficulty with mathematics. Taking into account the results of the factor analysis, the independent variables included 40 student variables and 40 teacher/principal variables in 2007 and 15 student variables and 37 teacher/principal variables in 2011. The reason for the difference between the numbers of students and teacher/principal variables in 2007 and 2011 is due to changes in the student, teacher, and principal questionnaires. Since students were selected from classes that were nested within schools, HLM analyses were used to analyze the data. Specifically, for each year, 2-level HLM analyses were conducted in five steps. The first step was the null model with no student or teacher/principal variables. The second and third steps were, respectively, the students' model with all the student variables but no teacher/principal variables and the teacher/principal model with all the teacher/principal variables but no student variables. The fourth step was full model with the 40/15 student and 40/37 teacher/principal variables. Using the results from the fourth step, the parsimonious model was developed independently for each year that contained only the significant predictors at each level taking into account correlation between the two levels.

## Summary of Results

As foreshadowed above, the results for the two years were different because of the different number of independent variables at each level between the two years. Therefore, the summary of results to be presented next and the discussion of these results in the next section are presented by year.

## Results for 2007

### *Student Level*

Of the 40 student variables that were considered, 20 were found to be significant and retained in the parsimonious model. The findings for the 20 significant student level variables are provided below. Given this is a causal study and not a cause-and-effect study, no cause-and-effect interpretations can be made. For example, boys outperformed girls means that generally more boys received higher scores than girls and fewer boys received lower scores than girls. Students having more books at home obtained lower scores in mathematics than students with fewer books at home is interpreted the same way: more students with more books at home received lower scores than students with fewer books at home and more students with more books at home received lower scores that students with fewer books at home.

1. Students' gender: males outperformed girls.
2. Number of books at student's home: students having more books at home obtained lower scores in mathematics than students with fewer books at home.
3. Home possessions: students living in homes with more home possessions obtained lower mathematics scores than students living in homes with fewer of the home possessions.

4. Students' educational aspirations: students with higher educational aspirations obtained higher scores than students with lower educational aspirations.
5. Students' self-confidence in mathematics: students with higher self-confidence in mathematics outperformed students with low self-confidence in mathematics.
6. Value of mathematics: students that placed high value on mathematics outperformed students that placed low value on mathematics.
7. Perceived difficulty: students who stated that mathematics was boring, not one of my strength, and difficult obtained lower scores than students who were not bored and did not find mathematics difficult.
8. Students' perception of the school: students that held positive perceptions of their schools outperformed students with low perceptions of their schools.
9. Safety of students: students who felt hurt by other students, bullied, and had their belongings stolen while in school obtained lower scores than students who felt safe in school.
10. Time on homework: students who spent more time doing their homework outperformed students who spent less time on their homework.
11. Students who frequently practiced adding, subtracting, multiplying, and dividing without using a calculator obtained higher scores than students who infrequently practiced adding, subtracting, multiplying, and dividing without using a calculator.
12. Students who frequently solve problems about geometric shapes obtained lower scores in mathematics than students who infrequently solve problems about geometric shapes.
13. Students who frequently decide on their own procedures for solving complex problems performed less well than students who infrequently decide on their own procedures.

14. Students who frequently begin their homework in class performed less well than students who infrequently begin their homework in class.
15. Students who frequently use calculators obtained lower scores than students who infrequently use calculators.
16. Students who frequently use computers obtained lower scores than students who less frequently use computers.
17. Students who spent more time outside of the school doing their homework outperformed students who spent less time outside of the school doing mathematics homework.
18. Students who spent more time outside of the school working at paid jobs performed less well than students who did not work at paid jobs.
19. Students who spent more time outside of the school surfing the internet obtained lower scores than students who spent less time outside the school browsing the internet.
20. Students who spent more time outside the school reading book for enjoyment outperformed students who spent less time outside the school reading book for enjoyment.

*Teacher/Principal Level*

Of the 40 teacher/principal variables that were considered, five were significant and retained in the parsimonious model. The significant teacher/principal variables included;

1. Teaching license or certificate: students taught by certified or licensed teachers performed less well than students taught by teachers without teaching license.
2. Mathematics education: students taught by teachers with a mathematics education major outperformed students taught by teachers without mathematics education major.

3. Amount of homework: students whose teachers frequently assigned them homework outperformed students taught by teachers who less frequently assigned mathematics homework.
4. Teachers' instructional practices: students taught by teachers who frequently engage them in instructional activities performed at higher level in mathematics than students with teachers who did not frequently engage them with instructional activities.
5. Principal's perception of the school: students attending schools where the principals held a positive perception of their school outperformed students from schools where the principals held negative perception of their school.

*Proportion of Variance Explained*

The proportion of variance in the mathematics scores explained by the 20 variables retained at student level was 27.3% of the total student variance. The five teacher/principal variables in the parsimonious model explained 54.7% of the total teacher/principal variance.

**Results for 2011**

*Student Level*

Of the 15 variables that were considered, nine were found to be significant and retained in the parsimonious model. The nine significant student level variables were;

1. Students' gender: males outperformed girls.
2. Students' educational aspirations: students with higher educational aspirations obtained higher scores than students with lower educational aspirations.
3. Students' self-confidence in mathematics: students with higher self-confidence in mathematics outperformed students with low self-confidence in mathematics.

4. Value of mathematics: students that place high value on mathematics outperformed students that placed low value on mathematics.
5. Perceived difficulty: students who stated that mathematics was boring and difficult obtained lower scores than students who were not bored and did not find mathematics difficult.
6. Students' perception of the school: students that held positive perceptions of their schools outperformed students with low perceptions of their schools.
7. Safety of students: students who felt hurt by other students, bullied, and had their belongings stolen while in school performed lower than students who felt safe in school.
8. Frequency of homework: students who were frequently assigned mathematics homework outperformed students who were less frequently assigned mathematics homework.
9. Time on homework: students who spent more time doing their home outperformed students who spent less time on their homework.

*Teacher/Principal Level*

Of the 37 teacher/principal variables that were considered, seven were significant and retained in the parsimonious model. The significant teacher/principal variables included;

1. Mathematics major: students taught by teachers with a mathematics major outperformed students taught by teachers without mathematics major.
2. Science major: students taught by teachers with science major performed less well than students taught by teachers without a science major.
3. Science education major: students taught by teachers with science education major outperformed students taught by teachers without science education major.

4. Emphasis on class tests: students taught by teachers who placed much emphasis on class tests as a means of monitoring their progress tended to outperform students whose teachers places less emphasis on class tests.
5. Recall questions: students taught by teachers who frequently used questions based on recall of facts and procedures performed less well than students whose teachers infrequently used recall questions.
6. Teacher's perception of the school: students attending schools where the teachers held a positive perception of the school outperformed students from schools where the teachers held negative perception of the school.
7. School location: students attending schools in larger communities' outperformed students attending schools in smaller communities.

*Proportion of Variance Explained*

The proportion of variance in the mathematics scores explained by the nine significant student level predictors was 20.0% of the total variance at the student level. The seven teacher/principal variables explained 54.1% of the total variance at the teacher/principal level.

**Discussion of Results**

The results of this current study are consistent with the "Input-Process-Output" conceptual model that was adopted and guided the selection of variables. The results supported the notion that students learning and achievement are influenced by students' background variables, teacher/classroom characteristics, and school characteristics. The discussion of common student level predictors for 2007 and 20011 is presented first, followed by the discussion of the unique variables for 2007. There were no unique student variables for 2011.

The discussion of the teacher/principal variables is then presented. Since there were no common teacher principal variables, there are no subsections for teacher/principal.

**Effects of Student-level Predictors of Mathematics Achievement**

*Common Student Variables*

In both years, boys obtained higher mathematics achievement scores than girls. Further, Frempong (2010) found a similar result in his analysis of the TIMSS 2003 data from Ghana. This finding is not surprising because in Sub-Saharan Africa, boys have consistently outperformed girls in mathematics achievement (MoE, 2004, 2008; Chowa, Masa, Ramos, & Ansong, 2013; Bassey, Joshua, & Asim, 2011). Also analyzing the TIMSS (1995-2003) data from 16 countries, Neuschmidt, Barth, and Hastedt (2008) found that boys outperformed girls in 16 countries that participated in each of the TIMSS from 1995 to 2003. The low performance of girls in mathematics in Sub-Saharan Africa is partly due to the notion of most families concerning the education of their girl-children. In most low-income countries in Sub-Saharan Africa, most families consider the kitchen as the place for their daughters and hence invest more in the education of their sons in contrast to what happens in most western countries (Pekkarinen, 2008).

Student self-confidence in learning mathematics and the value students placed on mathematics were positively related to mathematics achievement in both 2007 and 2011. Similar to the findings of Chepete (2008), students who held high educational aspirations outperformed students who held low educational aspirations. These findings are similar to the findings of studies conducted in more developed countries like the United States and Canada (Broeck, Opdenakker, & Damme, 2005; House, 2003 & 2005; Ma & Kishor, 1997; Ma & Wilkins, 2003; Shavelson, McDonnell, & Oakes, 1989). Students who reported that mathematics was a boring and difficult subject obtained lower scores in the mathematics test than students who reported that mathematics was not a boring and difficult subject. This finding is consistent with the findings of House (2003) who investigated the relationship between students' self-beliefs and mathematics achievement among middle schools students in Hong Kong. Consistent with previous studies (e.g., Lee & Shute, 2010; Lubienski, Lubienski, & Crane, 2008), a positive school climate supported student learning and achievement in mathematics in Ghana. However, the lack of safety of students in schools negatively influenced mathematics achievement. Similar findings were reported by Chepete (2008) in his study of TIMSS 2003 data from Botswana, MoE (2004) in Ghana, and Gronna and Chin-Chance (1999) in their study of effects of school safety and school characteristics on grade eight mathematics achievement in 46 schools from an entire western state in the US. Gronna and Chin-Chance (1999) argued that schools with less violence, less theft rate, and less frequency of abusive language provided better and safer learning environments for students. Students in schools with unsafe learning environment would have less time to focus on academic work since a large part of the instructional time may be used in addressing disciplinary issues.

Whereas Phan (2008), Patterson, Perry, and Decker (2003), Rodriquez (2004), and Trautwein and Koller (2003) found that both the frequency and amount of mathematics homework positively influenced mathematics achievement, the findings were only partially replicated in the present study. While the amount of time students spent doing mathematics homework positively influenced mathematics achievement in 2007 and 2011, the frequency of homework positively influenced mathematics achievement in 2011 but not 2007. There is no ready explanation for this difference.

*2007 Student Variables*

In 2007, both the number of books and the possessions in a student's home were negatively related to mathematics achievement. This finding is in contrast to the results of previous studies (e.g., Mullis, et al., 2004; Chepete, 2008). Analyzing the TIMSS 2003 eight grade mathematics data to investigate the association between student mathematics achievement and home resources across the countries that participated, Mullis et al. (2004) found that in many countries, students from homes with a range of resources such as computers, calculators, study desks, and dictionary was positively related to mathematics achievement. Chepete (2008) found in his analysis of the TIMSS 2003 data at Grade eight in Botswana that the number of books and the possessions in the students' home were positively related to mathematics achievement. One possible explanation for the negative relationship between the number of books and mathematics achievement could have to do with the purpose of the ownership of books. In Ghana, it is a common practice to see many households using books that were hardly opened for decoration purposes. Further, the books in the home could actually be for the parents or elderly siblings and, therefore, not suitable for grade eight students to use for learning or as source of information.

In 2007, students were asked to indicate how often they were engaged in 17 instructional activities during their mathematics lessons. Of the 17 instructional variables, one – *we practice adding, subtracting, multiplying, and dividing without using a calculator* – positively influenced mathematics achievement, whereas five – *solve problems about geometric shapes, decide on our own procedures for solving complex problems*, *begin our homework in class*, *we use calculators*, and *we use computers* – negatively influenced mathematics achievement. This finding is somewhat consistent with the findings of Zuzovsky (2013) who employed hierarchical multilevel regression analysis to explore the relationship between the frequent use of the 17 instructional practices and mathematics achievement in low-, medium-, and high-achieving countries. Zuzovsky found that the frequent use of instructional practices targeted at developing computational skills such as *we practice adding, subtracting, multiplying, and dividing without using a calculator* were positively and significantly associated with mathematics achievement, with the stronger association in low-achieving countries. She also found that whereas the frequent use of the instructional variables *solve problems about geometric shapes, decide on our own procedures for solving complex problems*, *begin our homework in class*, *we use calculators*, and *we use computers* were negatively associated with mathematics achievement in low-achieving countries, *solve problems about geometric shapes, decide on our own procedures for solving complex problems and we use calculators* were positively associated with mathematics achievement in medium and, more-so, high-achieving countries.

The results of 2007 revealed that the more time students spent outside of the school working at paid jobs or using the internet, the poorer their performance in mathematics. Similarly, Post and Pong (2000) found a negative association between adolescent employment and mathematics achievement, especially for boys, in their investigation of students' employment on academic achievement during the middle school years by analyzing the NELS 1988 and the TIMSS 1995 data from the US and 22 other countries. Similarly, House and Telese (2012) found that, the more time students' spent outside the school playing computer games or browsing the internet, the lower their mathematics achievement scores.

**Effects of Teacher/Principal-level Predictors on Mathematics Achievement**

Students taught by teachers with teaching license or certificates performed less well in mathematics achievement than students taught by uncertificated teachers in 2007. In contrast Darling-Hammond (2000) found that students of teachers in the United States with full certification obtained higher scores in mathematics achievement. However and in agreement with Goldhaber and Brewer (1997), students in Ghana taught by teachers with a mathematics education major performed at a higher level than students taught by teachers who did not have a mathematics education major 2007. However in 2011, students with teachers with mathematics majors or science education majors obtained higher scores in mathematics than students with teachers who did not have these majors. Surprisingly, students with teachers with a science major performed less well. Interestingly teaching experience was not related to mathematics achievement in both years, which is in contrast to the findings of previous studies (Greenwald, Hedges, & Laine, 1996; Rice, 2003; Chidolue, 1996; Fetler, 2001). These findings reflect the mixed results in the literature concerning the relationship between teachers' qualifications, education, subject matter and pedagogical knowledge, teaching experience, and students' mathematics achievement (Darling-Hammond & Youngs, 2002; Akiba, LeTender & Scriber, 2007; Chepete, 2008; Kaplan & George, 1998; Rice, 2003; Wayne & Youngs, 2003; Wilson, Floden, & Ferrini-Mundy, 2002). Contrasting the findings of studies that found a significant association between teachers' background and students' achievement, Xin, Xu, and Tatsuoka (2004) found that teacher's qualifications, major field, and teaching experience were not positively correlated with students' achievement.

Students attending schools in larger communities outperformed students attending schools in smaller communities in 2011 but not 2007. Both the Ministries of Education for Ghana and Botswana reported that students from schools in the urban areas outperformed students from schools in the rural areas (Ghana MoE, 2004; Botswana MoE, 2005). Similar results were found by Frempong (2010), when he used HLM to analyze the 2003 TIMSS data from Ghana. He found that students from schools located in towns (urban areas) outperformed students attending schools in the villages or rural areas. Generally, better qualified teachers with more experience teach in urban schools than teachers who teach in rural schools (MoE, 2004; 2008).

Consistent with previous research (e.g., Phan, 2008; Patterson, Perry, & Decker, 2003; Rodriquez, 2004; Trautwein & Koller, 2003), the amount of mathematics homework teachers gave to their students was positively related to students' mathematics achievement in 2007. Similarly, students who were more engaged in the instructional practices performed at a higher level than students who were not so engaged in 2007. This finding is consistent with the findings of House and Telese (2011) who used the TIMSS 1995 data to investigate classroom strategies that are significantly related to mathematics learning and achievement and found that students' learning and achievement were higher in classes where teachers employed a variety of activities such as explanation of the rules and definitions, solved examples pertaining to new topics, and solved real life experiences related problems.

Interestingly, whereas students with a principal with a positive perception of their school outperformed students with a principal with a less positive perception of their school in 2007, students with teachers who had a positive perception of the school outperformed students with teachers who had a less positive perception of the school in 2011. Similar findings were reported by Lubienski, Lubienski, and Crane (2008) who observed that students attending schools where the teachers and the principals portray the school climate as positive obtained higher achievement scores.

Students with teachers who placed much emphasis on class tests as a means of monitoring students' progress obtained higher scores in mathematics than students with teachers who did not place much emphasis on class tests in 2011. In contrast, students whose teachers frequently used questions based on recall of facts and procedures performed less well than students whose teachers infrequently used recall questions. These findings connect well with existing literature because student responses to classroom activities and instructional tasks are influenced by the type of questions asked in class. For example, when students expect a multiple-choice test, they focus their learning and note-taking efforts on facts and details, whereas when students expect an essay test focus, they focus on main ideas (Nolen & Haladyna, 1990). Studies have also shown that when students are given performance assessment tests, their learning improves because they have the opportunity to reason, reflect, actively process information and make sound decisions on their own without promptings from teachers (Lane & Stone, 2006). Similarly, Stevenson, Lee, and Stigler (1986) suggested that when students are exposed to rigorous mathematics content material, their learning improves.

**Comparison of 2007 and 2011 Results**

Comparing the results of the 2007 and 2011 data indicates that, the strength of the association between eight common student level predictors and mathematics achievement was similar across the two years. Of the eight, six positively influenced students' mathematics achievement. These six variables were students' gender, educational aspiration, self-confidence in mathematics, value for mathematics, perception of the school, and the time spent doing mathematics homework. On the other hand, perceived difficulty of mathematics and students' safety in the school negatively influenced mathematics achievement.

Further, despite the difference in the number of retained variables at the student and teacher/principal levels between 2007 and 2011, the amount of explained variance at each level was approximately the same (27.3% vs. 20.0% and 54.7% vs. 54.1%). Similarly, Frempong (2010) found that about 70% of the variance was explained at the school level, and 9% of the variance explained at the student level. In contrast Rogers, Ma, et al. (2007) found that about 75% of the variance was accounted at the student level, 15% at the class level, and 10% of the variance at the school level for Reading and Mathematics end-of-year province-wide tests.

**Limitations of the Study**

One limitation of the current study is related to the source of literature that guided the selection of variables, informed the direction of data analyses and interpretation of the results. As stated in Chapter 1, not many studies have been conducted to examine students' mathematics achievement from developing countries; hence the literature reviewed was primarily from developed countries. In addition, not many African countries participated in the TIMSS assessments. It is therefore likely that this study might have ignored some important variables that are of particular importance in developing countries.

Grade eight students from private schools in Ghana did not participate in the 2007 and 2011 TIMSS. Students from private schools consistently outperformed their peers from public schools in the Ghana Basic Education Certificate Examination (BECE) (Aboagye, 2008). Inclusion of the students from the private schools in TIMSS would likely increase the performance of the Ghanaian sample and subsequently enhance Ghana's rankings within the rankings across countries completed and published by TIMSS. Consequently, the factors identified in the present study have application to the public schools and not necessarily the private schools.

A two-level (student, teacher/principal) rather than three-level (student, teacher/class, and principal/school) HLM analysis was completed for the 2007 and 2011 TIMSS. This was because in the TIMSS study, a two-stage stratified sampling was used; schools were selected first followed by random selection of intact classes from the selected schools. However, as seen in the Rogers, Ma, et al. (2007) HLM study in which a three-stage stratified sample was used, explainable variance was found at the student, teacher/class, and principal/school levels.

The last limitation was that it was not possible to make a clear comparison between the two years because of major changes made to the student and teacher questionnaires. For example, whereas the student questionnaire in TIMSS 2007 contained 17 instructional and nine out-of-school variables that were not included in the student questionnaire in TIMSS 2011, there were five home support questions in 2011 that were not asked in 2007.

**Conclusions**

Ghana, as a country, ranked second last, second last, and last for the 2003, 2007, and 2011 TIMMS assessments. In light of findings across years and the limitations of the study, it is concluded that the poor performance of Ghana as a country is at least partially attributable to lack of proper preparation of teachers in rural areas, questionable school climate and safety, emphasis on lower rather than higher thinking skills, inconsistent use of homework, failure to engage students in their learning, lack of progress of girls, lack of students' interest and confidence in mathematics, and students' lower educational aspiration.

**Implications for Practices**

In light of the conclusion, it is recommended that the Education Ministry and policymakers strive to find effective ways of making the school climate a safe environment for learning. It is also recommended that the Inspectorate Division of the Ghana Education Service strengthen its supervisory and monitoring activities to ensure that appropriate instructional activities and practices are taken place in Ghanaian classrooms. Further, steps should be taken to ensure that teachers frequently give mathematics homework that is of appropriate difficulty to challenge their students to think at higher cognitive levels and also to ensure that the homework is marked and reviewed in class.

Teacher training institutions need to revise their curriculum so that pre-service teachers will be given the opportunity to learn modern and innovative teaching methods and strategies and how to teach and assess higher and lower level thinking skills, problem solving, and reasoning. Pre-service teachers also need to become aware of how to engage their students more actively in their learning. Additionally more pre-service students should be encouraged into specialized mathematics and science training colleges to complete specialized mathematics and science specialties or majors. Further, in light of the findings, consideration should be given to requiring all pre-service teachers to obtain a B.Ed. with specialization in mathematics if they plan to teach mathematics.

In-service training should be offered regularly throughout the country to train teachers in the development of appropriate instructional activities and the construction of tests items that demand higher cognitive skills. In-service workshops should be offered to foster positive attitudes in students and to create a safe and trusted learning environment.

Lastly, the organizers of TIMSS should strive to maintain consistency in the variables measured through the student, teacher, and principal questionnaires. This will better facilitate the analysis trends across multiple testing periods. Further, the sample design should be modified to allow separation estimation of teacher/class and principal/school effects

**Recommendations for Future Research**

1. The population of students, teacher/classes, and principal/schools should be changed so that student in private schools and their teachers and principals of private schools are all part of the population to be sampled.

2. Consideration should be given to Ghana's continued participation in TIMSS and Ghana's participation in PISA.
3. Attention should be given to including student, teacher, and principal questionnaires for each administration of the BECE achievement data to provide a broader and holistic picture of Ghanaian students' performance in mathematics and identify factors that explain student mathematics achievement in Ghana.
4. Greater care should be paid to making changes in student, teacher, and principal questionnaires so that the changes do not destroy the longitudinal aspect of TIMSS.
5. Research is needed to fully explain the difference between the performance of boys and the performance of girls with the intent of introducing procedure to reduce this gender gap. Future research employing qualitative analytical approaches can provide some in-depth insight into this trend. For instance, an in-depth investigation of the possible causes of lower mathematics scores for girls.
6. Researchers from other African countries can replicate this study using their TIMSS data, or the fourth-grade mathematics data. Similarly, in the future, this study can be extended to the science achievement data as well as other large-scale datasets like PISA.

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## APPENDIX A

Table 1A:

*Student-level Variables*

| Variable name | Variable description |
|---|---|
| Gender | Are you a boy or girl?<br>1 = girl, 2 = boy |
| Testing language at home | How often do you speak language of test at home?<br>1 = always, 2 = almost always, 3 = sometimes, 4 = never |
| Father's educational level | The highest level of education completed by your father<br>1 = Primary school or did not go to school<br>1 = Junior secondary school,<br>2 = Senior secondary school,<br>3 = Postsecondary (Teacher/Nursing/Training),<br>4 = National Diploma (HND),<br>5 = First Degree,<br>6 = Second degree or above,<br>7 = I don't know. |
| Mother's educational level | The highest level of education completed by your mother. The same response options as the father's educational level. |
| Number of books | About how many books are there in your home?<br>1 = (0 - 10 books), 2 = (11 - 25 books), 3 = (26 - 100 books), 4 = (101- 200 books), 5 = (more than 200 books) |
| Amount of homework | How often does your teacher give you homework in maths?<br>1 = everyday, 2 = 3 or 4 times a week, 3 = 1 or 2 times a week, 4 = less than once a week, 5 = never |
| Time spent on homework | When you teacher gives you maths homework, about how many minutes do you usually spend on your homework?<br>1= zero minutes, 2= 1-15 minutes, 3=16-30 minutes, 4= 31-60 minutes, 5=61- 90 minutes, 6= more than 90 minutes |
| Educational aspiration | How far in school do you expect to go?<br>1 = Senior secondary<br>2 = Postsecondary (Teacher/Nursing/Training)<br>3 = National Diploma<br>4 = First degree<br>5 = Second degree or above<br>6 = I don't know |
| Self-confidence in learning mathematics | A composite variable created from four-point likert-scale items: How much do you agree with these statements about learning mathematics?<br>1) I like mathematics<br>2) I learn things quickly in mathematics<br>3) I enjoy learning mathematics |

| | |
|---|---|
| | 4) I usually do well in mathematics<br>5) I am good at working out difficult mathematics problems*<br>6) My teacher tells me I am good at mathematics*<br>7) My teachers thinks I can do well in mathematics*<br>1 = agree a lot, 2 = agree a little, 3 = disagree a little, 4 = disagree a lot |
| Students' valuing mathematics | How much do you agree with these statements about learning mathematics?<br>1) I think learning maths will help me in my daily life,<br>2) I need maths to learn other subjects,<br>3) I need to do well in maths to get the job i want,<br>4) I need to do well in maths to get the university of my choice,<br>5) I would like to take more maths in school<br>6) I would like a job that involves using mathematics*<br>7) It is important to do well in mathematics*<br>Same response options as in self-confidence |
| Perceived Difficulty in mathematics | How much do you agree with these statements about learning mathematics?<br>1) Mathematics is boring<br>Mathematics is more difficult for me than for many of my classmates<br>1) Mathematics is not one of my strengths<br>2) Mathematics makes me confused and nervous*<br>3) Mathematics is harder for me than any other subject*<br>4) I wish I did not have to study mathematics*<br>Same response options as in self-confidence |
| Home possessions | Composite variable created by summing students' response for eight variables.<br>Do you have any of these things at your home? 1) calculator, 2) computer, 3) study desk, 4) dictionary, 5) electricity at home, 6) car/motorbike/bicycle, 7) tap water, 8 ) chalk/blackboard.<br>1 = yes, 2 = no |
| Home support* | Composite variables created by summing students responses to the following items;<br>How often do the following things happen at home?<br>1. My parents ask me what I am learning in school<br>2. I talk about my schoolwork with my parents<br>3. My parents make sure that I set aside time for my homework<br>4. My parents check if I do my homework<br>(1= every day or almost every day, 2= once or twice a week, 3= once or twice a month, 4= never or almost never) |
| 17 Instructional variables** | How often do you do these things in your maths lessons?<br>1) we practice adding, subtracting, multiplying, and dividing without using calculator<br>2) we work on fractions and decimals |

| | |
|---|---|
| | 3) we solve problems about geometric shapes, lines, and angles<br>4) we interpret data in tables, charts, or graphs<br>5) We write equations and functions to represent relationships.<br>6) We memorize formulas and procedures<br>7) We explain our answers<br>8) We relate what we are learning in mathematics to our daily lives<br>9) We decide on our own procedures for solving complex problems<br>10) We review our homework<br>11) We listen to the teacher give a lecture-style presentation<br>12) We work problems on our own<br>13) We work together in small groups<br>14) We begin our homework in class<br>15) We have a quiz or test<br>16) We use calculators<br>17) We use computers<br>1 = every or almost every lesson, 2 = about half the lessons, 3 = some lessons, 4 = never |
| Student perception of the school | Composite variable created from 3 four-point items.<br>How much do you agree with these statements about your school?<br>1) I like being in school,<br>2) I think that students in my school try to do their best,<br>3) I think that teachers in my school want students to do their best.<br>1 = agree a lot, 2 = agree a little, 3 = disagree a little, 4 = disagree a lot. |
| Out-of-school activities** | Composite variables computed from students' responses to the following 9 items.<br>On a normal school day, how much time do you spend before or after school doing each of these things?<br>1) I watch television and videos<br>2) I play computer games<br>3) I play or talk with friends<br>4) I do jobs at home<br>5) I work at a paid job<br>6) I play sports<br>7) I read a book for enjoyment<br>8) I do homework<br>9) I use the internet<br>1 = no time, 2 = less than 1 hour, 3 = 1- 2 hours, 4 = more than 2 hours but less than 4 hours, 5 = 4 or more hours |
| Students' feeling of safety in the school | Composite variable created by averaging student responses to 5 items.<br>In school, did any of these things happen during the last month? |

| | |
|---|---|
| | (1 = yes, 2 = no)<br>1) Something of mine was stolen<br>2) I was hit or hurt by other students<br>3) I was made to do things i didn't want to do by others<br>4) I was made fun of or called names<br>5) I was left out of activities by other students |

** variables measured in only 2007
* variables measured only in 2011

Table 2A: *Teacher, Classroom and School-level variables*

| Variable | Variable Description |
|---|---|
| Teacher's gender | Are you a male or female? (1 = yes, 2 = no) |
| Teachers' qualification | The highest level of formal education completed by teachers |
| Teaching experience | Number of years of teaching |
| Teacher's major of study | During your post-secondary education, what was your major or main area(s) of study?<br>1) Mathematics<br>2) mathematics education<br>3) Science<br>4) Science education<br>5) Education-General<br>6) Other (1 = yes, 2 = no) |
| Teacher's certification** | Do you have a teaching license or certificate? (1 = yes, 2 = no) |
| Ready to teach number | Composite variable computed by summing teacher's response to the following items;<br>How well ready do you feel you are to teach the following topics?<br>1. Computing, estimating or approximating with whole numbers<br>2. Representing decimals and fractions using words, numbers, or models<br>3. Computing with fractions<br>4. Representing, comparing, ordering, and computing with integers<br>5. Problem solving involving percents and proportions<br>1 = very ready, 2 = ready, 3 = not ready |
| Ready to teach algebra | 1. Numeric, algebraic, and geometric patterns and sequence<br>2. Simplifying and evaluating the algebraic expressions<br>3. Simple linear equations and inequalities, and simultaneous equations<br>4. Equivalent representations of functions as ordered pairs, tables, graphs, words, or equations<br>1 = very ready, 2 = ready, 3 = not ready |
| Ready to teach geometry | 1. Geometric properties of angles and geometric shapes<br>2. Congruent figures and similar triangles<br>3. Relationship between three-dimensional shapes and their two-dimensional representation<br>4. Using appropriate measurement formulas for perimeters, circumferences, areas of circles, surface areas and volumes<br>5. Cartesian plane-ordered pairs, equations, |

| | |
|---|---|
| | intercepts, intersections, and gradient<br>6. Translation, reflection, and rotation<br>1 = very ready, 2 = ready, 3 = not ready |
| Ready to teach Data and chance | 1. Reading and displaying data using tables, pictographs, bar graphs, pie charts and line graphs<br>2. Interpreting data sets<br>3. Judging, predicting, and determining the chances of possible outcomes<br>1 = very ready, 2 = ready, 3 = not ready |
| Teacher beliefs | A composite variable created from 5 items indexing the beliefs teachers hold for mathematics;<br>To what extent do you agree with the following;<br>1. There are different ways to solve most maths problems<br>2. One should use more than one representation to teach maths<br>3. Learning maths mainly involve memorizing<br>4. Solving maths involves the use of investigation and hypothesis testing<br>5. Maths should be learned as sets of algorithms<br>1=agree a lot, 2= agree a little, 3 = disagree a little, 4 = disagree a lot |
| Mathematics-related professional development | In the past two years, have you participated in professional development in any of the following? (1 = yes, 2 = no)<br>1) mathematics content<br>2) mathematics pedagogy/instruction<br>3) mathematics curriculum<br>4) mathematics assessment<br>5) integrating information technology into mathematics |
| Teacher's Instructional practices | A composite variable computed by summing teachers' responses to 12 instructional activities items. (1 = every or almost every lesson, 2 = about half lessons, 3 = some lessons, 4 = never)<br>In teaching mathematics to the students in the TIMSS class, how often do you usually ask them to do the following?<br>1. Practice adding, subtracting, multiplying, and dividing without using calculator<br>2. Work on fractions<br>3. Use knowledge of the properties of shapes, lines and angles to solve problems<br>4. Interpret data in tables, charts or graphs<br>5. Write equations and functions to represent relationships<br>6. Memorize formulas and procedures<br>7. Apply facts, concepts and procedures to solve routine problems<br>8. Explain their answers |

| | |
|---|---|
| | 9. Relate what they are learning in mathematics to their daily lives<br>10. Decide on their own procedures for solving complex problems<br>11. Work on problems for which there is no immediately obvious methods of solution<br>12. Work together in small groups |
| Mathematics Teachers' Perception of School Climate | A composite variable computed by summing the teachers' responses to the eight items that measure teachers' perception of the school climate.<br>How would you characterize each of the following within your school? (1 = high, 2 = medium, 3 = low)<br>1. Teachers' job satisfaction<br>2. Teachers' understanding of the school's curricular activities<br>3. Teachers' degree of success in implementing the school's curriculum<br>4. Teachers' expectations for student achievement<br>5. Parental support for student achievement<br>6. Parental involvement in school activities<br>7. Students' regard for school property<br>8. Students' desire to do well in school |
| Mathematics teachers' perception of school facility and safety | A composite variable created from 3 four-point Likert-scale items measuring teachers' perceptions about the school facility and safety (1 = agree a lot, 2 = agree a little, 3 = disagree a little, 4 = disagree a lot)<br>Thinking about your current school, indicate the extent to which you agree or disagree with each of the following statements.<br>1) The school is located in a safe neighborhood<br>2) I feel safe at this school<br>3) This school's security policies and practices are sufficient. |
| Limiting mathematics instruction due to student factors | A composite to be computed by averaging teachers' response to the following six items:<br>In your view, to what extent do the following limit how you teach the TIMSS class? (0 = not applicable, 1 = a little, 2 = some, 3 = a lot)<br>1) Students with different abilities<br>2) Students who come from a wide range of backgrounds<br>3) Students with special needs<br>4) Uninterested students<br>5) Low morale among students<br>6) Disruptive students |
| Opportunity to learn number | Composite variable computed as an average percent of students whose teachers selected options 1 and 2 for the 10 items of the number domain (1 = mostly taught before this year, 2 = mostly |

| | |
|---|---|
| | taught this year, 3 = not yet taught or just introduced).<br>1. Whole numbers including place value, factorization, and the four operations<br>2. Computations, estimations, or approximations involving whole numbers<br>3. Common fractions including equivalent fractions and ordering<br>4. Decimal including place value, ordering, and converting to common fractions<br>5. Representing decimals and fractions using words, numbers, or models<br>6. Computations with fractions<br>7. Computations with decimals<br>8. Representing, comparing, ordering, and comparing with integers<br>9. Ratios<br>10. Conversion of percents to fractions or decimals and vice versa |
| Opportunity to learn algebra | Composite variable computed as the average percent of students whose teachers selected options 1 and 2 for the 8 items of the algebra domain (same response options as the number strand).<br>1. numeric, algebraic, and geometric patterns and sequences<br>2. sums, products, and powers of expressions containing variables<br>3. evaluating expressions for given numeric values<br>4. simplifying or comparing algebraic expressions<br>5. modeling situations using expressions<br>6. evaluating functions/formulas for given values of the variables<br>7. simple linear equations and inequalities, and simultaneous equations<br>8. equivalent representations of functions as ordered pairs, tables, graphs, words, or equations |
| Opportunity to learn geometry | composite variable created the same way as the above variables but using the 14 items on the geometry domain<br>1. angles – acute, right, straight, obtuse, reflex<br>2. relationships for angles at a point, angles on a line, vertically opposite angles, angles associated with parallel lines<br>3. properties of geometric shapes<br>4. construct or draw triangles and rectangles of given dimensions<br>5. congruent figures and their corresponding measures<br>6. similar triangles and recall their properties |

| | |
|---|---|
| | 7. relationships between two- and three-dimensional shapes<br>8. Pythagorean theorem to find length of a side<br>9. Measurement, drawing, and estimation of the size of angles, the lengths of lines, areas, and volumes<br>10. Measurement formulas for perimeters, circumferences, surfaces, areas and volumes<br>11. Measures of irregular or compound areas<br>12. Cartesian plane<br>13. Line and rotational symmetry for two-dimensional shapes<br>14. Translation, reflection, and rotation |
| Opportunity to learn data and chance | Composite variable to be created from the 7 items on the data and chance domain.<br>1. Reading data from tables, pictographs, bar graphs, pie charts, and line graphs<br>2. Organizing and displaying data using graphs<br>3. Characteristics of data sets including mean, median, range, and shape of distribution<br>4. Interpreting data sets<br>5. Data displays that could lead to misinterpretation<br>6. Using data from experiments to predict chances of future outcomes<br>7. Using the chances of a particular outcome to solve problems |
| Amount of homework | Composite variable with 3 point-scale: 1 = high, 2 = medium, 3 = low, to be created using the following two variables.<br>1) Do you assign mathematics homework to the TIMSS class? (1 = yes, 2 = no)<br>2) How often do you usually assign mathematics homework to the TIMSS class? (1 = every or almost every lesson, 2 = about half of the lessons, 3 = some lessons) |
| Monitoring students' progress | How much emphasis do you place on the following sources to monitor students' progress in mathematics?<br>1) Classroom tests (for example, teacher made or textbook tests)<br>2) National or regional achievement tests<br>3) Your professional judgement |
| Item formats | What item formats do you typically use in your mathematics tests or examination?<br>1 = mostly or only constructed-response<br>2 = about half constructed-response and half objective (e.g., multiple-choice)<br>3 = mostly or only objective. |
| Question type | How often do you include the following types of questions in |

| | |
|---|---|
| | your mathematics tests or examinations?<br>1) Questions based on recall of facts and procedures<br>2) Questions involving application of mathematical procedures<br>3) Questions involving searching for patterns and relationships<br>4) Questions requiring explanations or justifications |
| School location | 1 = rural, 2 = semi-urban, 3 = urban |
| Class size | How many students are in the TIMSS class? |
| Principal's perception of school climate | A composite variable computed by summing the principal's responses to the eight items that measure their perceptions of the school climate.<br>How would you characterize each of the following within your school? (1 = High, 2 = medium, 3 = low)<br>1. Teachers' job satisfaction<br>2. Teachers' understanding of the school's curricular activities<br>3. Teachers' degree of success in implementing the school's curriculum<br>4. Teachers' expectations for student achievement<br>5. Parental support for student achievement<br>6. Parental involvement in school activities<br>7. Students' regard for school property<br>8. Students' desire to do well in school |
| Expected parental involvement | Composite variable created from the principal's responses to the following items.<br>Does your ask parents to do the following? (1 = yes, 2 = no)<br>1) Attend special events (e.g., science fair, sporting events)<br>2) Raise funds for the school<br>3) Volunteer for school projects, programs, and trips<br>4) Ensure that their child completes his/her homework<br>5) Serve on school management committees (e.g., select school personnel, review school finances) |
| Evaluation of mathematics teachers | A composite variable created from principals' responses to the following methods of evaluating the work of mathematics teachers.<br>In your school, are any of the following used to evaluate the practices of mathematics teachers? (1 = yes, 2 = no)<br>1) Observations by the principal or senior staff<br>2) Observations by inspectors or other persons external to the school<br>3) Student achievement<br>4) Teacher peer review |
| Availability of school | Composite variable with a 3 point-scale: 1 = high, 2 = medium, |

| | |
|---|---|
| resources for mathematics instruction | 3 = low computed from the principal's responses to the following 10 items.<br>Is your school's capacity to provide instruction affected by shortage or inadequacy of any of the following?<br>1) Instructional materials (e.g., textbook)<br>2) Budgets for supplies (e.g., paper, pencil)<br>3) School buildings and grounds<br>4) Heating/cooling and lighting systems<br>5) Instructional space (e.g., classrooms)<br>6) Computers for mathematics instruction<br>7) Computer software for mathematics instruction<br>8) Calculators for mathematics instruction<br>9) Library materials relevant to mathematics instruction<br>10) Audio-visual resources for mathematics instruction |

# APPENDIX B- TIMSS 2007 RESULTS

Table 1

*Descriptive statistics for the Level-1 and -2 predictors*

| VARIABLE NAME | N | MEAN | SD | MINI | MAX |
|---|---|---|---|---|---|
| **STUDENTS LEVEL** | | | | | |
| sex of student | 5235 | 1.54 | 0.50 | 1 | 2 |
| language at home | 5235 | 2.5 | 0.86 | 1 | 4 |
| number of books | 5235 | 2.14 | 1.19 | 1 | 5 |
| mother's education | 5235 | 1.99 | 1.53 | 0 | 7 |
| father's education | 5235 | 2.61 | 1.89 | 0 | 7 |
| educational aspiration | 5235 | 3.28 | 1.53 | 1 | 5 |
| home possessions | 5235 | 11.34 | 2.00 | 8 | 16 |
| self-confidence | 5235 | 7.21 | 2.89 | 4 | 16 |
| value of mathematics | 5235 | 7.17 | 2.8 | 5 | 20 |
| perceived difficulty | 5235 | 7.9 | 2.49 | 3 | 12 |
| students perception of school | 5235 | 3.82 | 1.63 | 3 | 12 |
| students safety in school | 5235 | 8.03 | 1.33 | 5 | 16 |
| practice four operations | 5235 | 2.11 | 1.22 | 1 | 4 |
| work on fractions & decimals | 5235 | 2.24 | 0.93 | 1 | 4 |
| solve geometric problems | 5235 | 2.36 | 0.92 | 1 | 4 |
| interpret tables & charts | 5235 | 2.39 | 0.96 | 1 | 4 |
| write equations & functions | 5235 | 2.37 | 0.99 | 1 | 4 |
| memorize formulas | 5235 | 2.23 | 1.09 | 1 | 4 |
| explain our answers | 5235 | 1.73 | 1.01 | 1 | 4 |
| relate maths to daily life | 5235 | 1.88 | 1.01 | 1 | 4 |
| decide our own procedures | 5235 | 2.38 | 1.09 | 1 | 4 |
| review our homework | 5235 | 1.82 | 1.06 | 1 | 4 |
| listen to teacher lectures | 5235 | 1.97 | 1.17 | 1 | 4 |
| work problems our own | 5235 | 2.33 | 1.11 | 1 | 4 |
| work together in groups | 5235 | 2.49 | 1.07 | 1 | 4 |
| begin homework in class | 5235 | 3.37 | 1.04 | 1 | 4 |
| have a quiz | 5235 | 2.14 | 1.04 | 1 | 4 |
| use calculators | 5235 | 3.41 | 0.89 | 1 | 4 |
| use computers | 5235 | 3.63 | 0.83 | 1 | 4 |
| frequency of homework | 5235 | 2.09 | 0.99 | 1 | 5 |
| time spent on homework | 5235 | 3.37 | 1.18 | 1 | 5 |
| watch TV & videos | 5235 | 1.94 | 1.00 | 1 | 5 |
| play computer games | 5235 | 1.62 | 1.03 | 1 | 5 |
| talk with friends | 5235 | 2.26 | 1.12 | 1 | 5 |
| do jobs at home | 5235 | 2.6 | 1.35 | 1 | 5 |
| work at paid jobs | 5235 | 1.69 | 1.14 | 1 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| play sports | 5235 | 2.05 | 1.07 | 1 | 5 |
| read book for enjoyment | 5235 | 2.81 | 1.24 | 1 | 5 |
| use the internet | 5235 | 1.66 | 1.07 | 1 | 5 |
| do my homework | 5235 | 2.69 | 1.13 | 1 | 5 |
| TOTWGT | 5235 | 63.39 | 31.33 | 13.27 | 138.89 |
| PV_1 | 5235 | 318.08 | 90.1 | 5 | 599.14 |
| PV_2 | 5235 | 316.74 | 91.97 | 5.16 | 622.12 |
| PV_3 | 5235 | 316.14 | 93.23 | 5 | 637.49 |
| PV_4 | 5235 | 316.9 | 91.31 | 5 | 624.03 |
| PV_5 | 5235 | 318.86 | 91.35 | 5 | 634.98 |
| **TEACHER/PRINCIPAL LEVEL** | | | | | |
| MATWGT | 162 | 74.14 | 31.82 | 11.26 | 138.89 |
| teacher's gender | 162 | 1.91 | 0.29 | 1 | 2 |
| teaching experience | 162 | 7.77 | 7.23 | 1 | 33 |
| teacher's formal education | 162 | 3.18 | 0.8 | 2 | 5 |
| mathematics major | 162 | 1.37 | 0.48 | 1 | 2 |
| science major | 162 | 1.62 | 0.49 | 1 | 2 |
| mathematics education | 162 | 1.47 | 0.5 | 1 | 2 |
| science education | 162 | 1.71 | 0.46 | 1 | 2 |
| education general | 162 | 1.53 | 0.5 | 1 | 2 |
| other | 162 | 1.63 | 0.48 | 1 | 2 |
| teaching license/certificate | 162 | 1.25 | 0.44 | 1 | 2 |
| class size | 162 | 2.22 | 0.76 | 1 | 3 |
| class test | 162 | 1.37 | 0.86 | 1 | 4 |
| national test | 162 | 2.29 | 1.06 | 1 | 4 |
| professional judgment | 162 | 1.85 | 1.01 | 1 | 4 |
| testing frequency | 162 | 1.88 | 0.85 | 1 | 4 |
| test item format | 162 | 2.67 | 0.7 | 1 | 5 |
| recall questions | 162 | 1.46 | 0.54 | 1 | 3 |
| application questions | 162 | 1.35 | 0.5 | 1 | 3 |
| pattern & relationship quest | 162 | 1.93 | 0.53 | 1 | 3 |
| explanation questions | 162 | 1.72 | 0.58 | 1 | 3 |
| teacher's perception of school | 162 | 21.89 | 4.39 | 12 | 33 |
| teacher's safety in school | 162 | 7.06 | 2.18 | 3 | 12 |
| teacher's belief | 162 | 13.71 | 3.03 | 6 | 24 |
| limiting students factors | 162 | 16.83 | 3.27 | 9 | 25 |
| teacher's instructional practices | 162 | 13.1 | 3.26 | 6 | 23 |
| professional development | 162 | 9.59 | 1.99 | 6 | 12 |
| homework | 162 | 2.65 | 0.84 | 1 | 5 |
| opportunity to learn number | 162 | 15.2 | 3.87 | 10 | 28 |
| opportunity to learn algebra | 162 | 15.74 | 3.28 | 8 | 24 |
| opportunity to learn geometry | 162 | 30.24 | 5.36 | 14 | 41 |
| opportunity to learn data | 162 | 15.31 | 3.65 | 7 | 21 |

| | | | | | |
|---|---|---|---|---|---|
| ready to teach number | 162 | 10.73 | 1.5 | 10 | 20 |
| ready to teach algebra | 162 | 8.59 | 1.11 | 8 | 16 |
| ready to teach geometry | 162 | 13.62 | 2.29 | 12 | 24 |
| ready to teach data | 162 | 6.85 | 1.3 | 6 | 12 |
| school location | 162 | 4.11 | 2.01 | 1 | 6 |
| resources for maths | 162 | 25.38 | 8.21 | 12 | 42 |
| parental involvement | 162 | 6.25 | 1.17 | 5 | 10 |
| principal's perception of school | 162 | 20.54 | 4.63 | 10 | 33 |
| teacher's evaluation | 162 | 4.79 | 1.01 | 4 | 8 |

Table 2

*Student-level predictors*

| | *B* | *S.E* | *T-ratio* | *p-value* |
|---|---|---|---|---|
| **sex of student** | **15.80** | **2.60** | **6.09** | **0.000** |
| language at home | 1.84 | 1.45 | 1.26 | 0.225 |
| **number of books** | **-1.99** | **0.91** | **-2.18** | **0.035** |
| mother's education | -0.22 | 0.81 | -0.28 | 0.785 |
| father's education | 0.99 | 0.64 | 1.52 | 0.137 |
| **educational aspiration** | **4.19** | **0.65** | **6.47** | **0.000** |
| **home possessions** | **-3.78** | **1.50** | **-2.51** | **0.022** |
| **self-confidence** | **13.52** | **1.34** | **10.12** | **0.000** |
| **value of mathematics** | **7.47** | **2.13** | **3.51** | **0.010** |
| **perceived difficulty** | **-11.49** | **2.05** | **-5.60** | **0.001** |
| **students perception of school** | **4.94** | **1.55** | **3.19** | **0.009** |
| **students safety in school** | **-2.23** | **1.03** | **-2.17** | **0.034** |
| **practice four operations** | **5.95** | **1.14** | **5.24** | **0.000** |
| work on fractions & decimals | -2.52 | 1.41 | -1.78 | 0.091 |
| **solve geometric problems** | **-3.82** | **1.58** | **-2.41** | **0.033** |
| interpret tables & charts | -2.03 | 1.16 | -2.40 | 0.087 |
| write equations & functions | -1.84 | 1.21 | -1.52 | 0.139 |
| memorize formulas | 0.86 | 1.50 | 0.58 | 0.580 |
| explain our answers | 2.56 | 1.35 | 1.90 | 0.079 |
| relate maths to daily life | -0.76 | 1.80 | -0.42 | 0.685 |
| **decide our own procedures** | **-2.89** | **1.12** | **-2.58** | **0.017** |
| review our homework | 1.17 | 1.21 | 0.97 | 0.345 |
| listen to teacher lectures | -0.52 | 1.37 | -0.38 | 0.715 |
| work problems our own | -2.01 | 1.23 | -1.64 | 0.127 |
| work together in groups | -1.06 | 1.12 | -0.95 | 0.353 |
| **begin homework in class** | **-7.88** | **1.59** | **-4.96** | **0.001** |
| have a quiz | 2.03 | 1.09 | 1.87 | 0.070 |
| **use calculators** | **-4.77** | **1.66** | **-2.87** | **0.014** |
| **use computers** | **-6.91** | **1.47** | **-4.71** | **0.000** |
| frequency of homework | 0.67 | 1.50 | 0.45 | 0.665 |
| **time spent on homework** | **4.16** | **1.12** | **3.73** | **0.003** |
| watch TV & videos | -0.52 | 1.16 | -0.45 | 0.656 |
| play computer games | -2.29 | 1.24 | -1.85 | 0.082 |
| talk with friends | 2.06 | 1.38 | 1.49 | 0.170 |
| do jobs at home | 2.22 | 1.17 | 1.90 | 0.091 |
| **work at paid jobs** | **-3.40** | **1.11** | **-3.05** | **0.008** |
| play sports | 1.88 | 1.45 | 1.30 | 0.225 |
| **read book for enjoyment** | **2.16** | **0.89** | **2.44** | **0.019** |

| | | | | |
|---|---|---|---|---|
| **use the internet** | **-7.36** | **1.18** | **-6.24** | **0.000** |
| **do my homework** | **2.70** | **1.18** | **2.30** | **0.039** |

Table 3: *Teacher/Principal predictors*

| | *B* | *S.E* | *T-ratio* | *P-value* |
|---|---|---|---|---|
| teacher's gender | -8.24 | 14.71 | -0.56 | 0.576 |
| teaching experience | 0.68 | 0.67 | 0.99 | 0.323 |
| teacher's formal education | 4.42 | 6.48 | 0.68 | 0.500 |
| mathematics major | 8.61 | 10.13 | 0.85 | 0.397 |
| science major | 18.37 | 11.31 | 1.62 | 0.107 |
| **mathematics education** | **24.35** | **12.18** | **2.00** | **0.048** |
| science education | -0.24 | 13.66 | -0.02 | 0.986 |
| education general | -11.11 | 10.99 | -1.01 | 0.314 |
| other | -12.78 | 11.13 | -1.15 | 0.253 |
| **teaching license/certificate** | **-29.83** | **12.59** | **-2.37** | **0.019** |
| **class size** | **21.35** | **8.94** | **2.39** | **0.018** |
| class test | 7.14 | 5.80 | 1.23 | 0.220 |
| national test | 3.67 | 4.60 | 0.80 | 0.430 |
| professional judgment | -0.99 | 4.97 | -0.198 | 0.843 |
| testing frequency | 8.43 | 5.08 | 1.66 | 0.100 |
| test item format | -6.94 | 6.27 | -1.11 | 0.270 |
| recall questions | -11.59 | 8.34 | -1.38 | 0.169 |
| application questions | 4.38 | 8.83 | 0.50 | 0.621 |
| pattern & relationship quest | -4.86 | 9.68 | -0.50 | 0.617 |
| explanation questions | 6.42 | 8.45 | 0.76 | 0.449 |
| **teacher's perception of school** | **4.30** | **2.15** | **2.00** | **0.048** |
| teacher's safety in school | 3.71 | 2.15 | 1.73 | 0.087 |
| teacher's belief | 2.93 | 1.60 | 1.83 | 0.069 |
| limiting students factors | 2.85 | 1.45 | 1.97 | 0.055 |
| teacher's instructional practices | 1.48 | 1.67 | 0.89 | 0.375 |
| professional development | 0.86 | 2.15 | 0.40 | 0.688 |
| **homework** | **13.70** | **5.92** | **2.31** | **0.022** |
| opportunity to learn number | 0.14 | 1.23 | 0.11 | 0.910 |
| opportunity to learn algebra | -1.53 | 1.67 | -0.92 | 0.360 |
| opportunity to learn geometry | 0.23 | 1.10 | 0.21 | 0.838 |
| opportunity to learn data | 1.71 | 1.58 | 1.08 | 0.248 |
| ready to teach number | 4.33 | 3.58 | 1.21 | 0.228 |
| ready to teach algebra | 1.48 | 5.17 | 0.29 | 0.775 |
| ready to teach geometry | 1.78 | 2.64 | 0.68 | 0.500 |
| ready to teach data | -1.86 | 4.68 | 0.40 | 0.692 |
| school location | -0.27 | 2.23 | -0.12 | 0.905 |
| resources for maths | -0.56 | 0.55 | -1.02 | 0.309 |
| parental involvement | 2.02 | 3.67 | 0.55 | 0.583 |
| **principal's perception of school** | **3.57** | **1.04** | **3.42** | **0.001** |
| teacher's evaluation | 6.52 | 4.19 | 1.57 | 0.122 |

Table 4: *Full model*

| | *B* | *S.E* | *T-ratio* | *P-value* |
|---|---|---|---|---|
| **sex of student** | **16.00** | **2.75** | **5.83** | **0.000** |
| language at home | 1.84 | 1.45 | 1.26 | 0.225 |
| **number of books** | **-1.93** | **0.88** | **-2.18** | **0.033** |
| mother's education | -0.22 | 0.81 | -0.28 | 0.785 |
| father's education | 0.99 | 0.64 | 1.52 | 0.137 |
| **educational aspiration** | **4.82** | **0.89** | **5.39** | **0.000** |
| **home possessions** | **-3.78** | **1.5** | **-2.51** | **0.022** |
| **self-confidence** | **4.66** | **0.50** | **9.35** | **0.000** |
| **value of mathematics** | **2.73** | **0.84** | **3.26** | **0.017** |
| **perceived difficulty** | **-4.63** | **0.78** | **-5.92** | **0.001** |
| **students perception of school** | **2.88** | **0.97** | **2.97** | **0.014** |
| **students safety in school** | **-2.23** | **1.03** | **-2.17** | **0.034** |
| **practice four operations** | **5.95** | **1.14** | **5.24** | **0.000** |
| work on fractions & decimals | -2.52 | 1.41 | -1.78 | 0.091 |
| **solve geometric problems** | **-3.82** | **1.58** | **-2.41** | **0.033** |
| interpret tables & charts | -2.03 | 1.16 | -2.4 | 0.087 |
| write equations & functions | -1.84 | 1.21 | -1.52 | 0.139 |
| memorize formulas | 0.86 | 1.5 | 0.58 | 0.580 |
| explain our answers | 2.56 | 1.35 | 1.9 | 0.079 |
| relate maths to daily life | -0.76 | 1.8 | -0.42 | 0.685 |
| **decide our own procedures** | **-2.89** | **1.12** | **-2.58** | **0.017** |
| review our homework | 1.17 | 1.21 | 0.97 | 0.345 |
| listen to teacher lectures | -0.52 | 1.37 | -0.38 | 0.715 |

| | | | | |
|---|---|---|---|---|
| work problems our own | -2.01 | 1.23 | -1.64 | 0.127 |
| work together in groups | -1.06 | 1.12 | -0.95 | 0.353 |
| **begin homework in class** | **-7.88** | **1.59** | **-4.96** | **0.001** |
| **have a quiz** | **2.03** | **1.09** | **1.87** | **0.070** |
| **use calculators** | **-4.77** | **1.66** | **-2.87** | **0.014** |
| **use computers** | **-6.91** | **1.47** | **-4.71** | **0.000** |
| frequency of homework | 0.67 | 1.5 | 0.45 | 0.665 |
| **time spent on homework** | **4.16** | **1.12** | **3.73** | **0.003** |
| watch TV & videos | -0.52 | 1.16 | -0.45 | 0.656 |
| play computer games | -2.29 | 1.24 | -1.85 | 0.082 |
| talk with friends | 2.06 | 1.38 | 1.49 | 0.17 |
| do jobs at home | 2.22 | 1.17 | 1.9 | 0.091 |
| **work at paid jobs** | **-3.4** | **1.11** | **-3.05** | **0.008** |
| play sports | 1.88 | 1.45 | 1.3 | 0.225 |
| **read book for enjoyment** | **2.16** | **0.89** | **2.44** | **0.019** |
| **use the internet** | **-7.36** | **1.18** | **-6.24** | **0.000** |
| **do my homework** | **2.7** | **1.18** | **2.3** | **0.039** |
| **Teacher/Principal level** | | | | |
| teacher's gender | -8.24 | 14.71 | -0.56 | 0.576 |
| teaching experience | 0.68 | 0.67 | 0.99 | 0.323 |
| teacher's formal education | 4.42 | 6.48 | 0.68 | 0.500 |
| mathematics major | 8.61 | 10.13 | 0.85 | 0.397 |
| science major | 18.37 | 11.31 | 1.62 | 0.107 |
| mathematics education | 17.08 | 9.68 | 1.77 | 0.080 |
| science education | -0.24 | 13.66 | -0.02 | 0.986 |
| education general | -11.11 | 10.99 | -1.01 | 0.314 |
| other | -12.78 | 11.13 | -1.15 | 0.253 |
| **teaching license/certificate** | **-21.91** | **10.35** | **-2.12** | **0.036** |

| | | | | |
|---|---|---|---|---|
| **class size** | **21.35** | **8.94** | **2.39** | **0.018** |
| class test | 7.14 | 5.8 | 1.23 | 0.220 |
| national test | 3.67 | 4.6 | 0.8 | 0.430 |
| professional judgment | -0.99 | 4.97 | -0.198 | 0.843 |
| testing frequency | 8.43 | 5.08 | 1.66 | 0.100 |
| test item format | -6.94 | 6.27 | -1.11 | 0.270 |
| recall questions | -11.59 | 8.34 | -1.38 | 0.169 |
| application questions | 4.38 | 8.83 | 0.5 | 0.621 |
| pattern & relationship quest | -4.86 | 9.68 | -0.5 | 0.617 |
| explanation questions | 6.42 | 8.45 | 0.76 | 0.449 |
| teacher's perception of sch | 0.51 | 0.87 | 0.59 | 0.560 |
| teacher's safety in school | 3.71 | 2.15 | 1.73 | 0.087 |
| teacher's belief | 2.93 | 1.6 | 1.83 | 0.069 |
| limiting students factors | 2.85 | 1.45 | 1.97 | 0.055 |
| teacher's instructional pract | 1.48 | 1.67 | 0.89 | 0.375 |
| professional development | 0.86 | 2.15 | 0.4 | 0.688 |
| **homework** | **10.61** | **4.76** | **2.23** | **0.028** |
| opportunity to learn number | 0.14 | 1.23 | 0.11 | 0.910 |
| opportunity to learn algebra | -1.53 | 1.67 | -0.92 | 0.360 |
| opportunity to learn geometry | 0.23 | 1.1 | 0.21 | 0.838 |
| opportunity to learn data | 1.71 | 1.58 | 1.08 | 0.248 |
| ready to teach number | 4.33 | 3.58 | 1.21 | 0.228 |
| ready to teach algebra | 1.48 | 5.17 | 0.29 | 0.775 |
| ready to teach geometry | 1.78 | 2.64 | 0.68 | 0.500 |
| ready to teach data | -1.86 | 4.68 | 0.4 | 0.692 |
| school location | -0.27 | 2.23 | -0.12 | 0.905 |

| | | | | |
|---|---|---|---|---|
| resources for maths | -0.56 | 0.55 | -1.02 | 0.309 |
| parental involvement | 2.02 | 3.67 | 0.55 | 0.583 |
| **principal's perception of school** | **2.10** | **0.87** | **2.42** | **0.017** |
| teacher's evaluation | 6.52 | 4.19 | 1.57 | 0.122 |

## APPENDIX C- TIMSS 2011 RESULTS

Table 1:

*Descriptive Statistics for the Level-1 and -2 Predictors*

| VARIABLE NAME | N | MEAN | SD | MIN | MAX |
|---|---|---|---|---|---|
| **STUDENTS LEVEL** | | | | | |
| student gender | 7304 | 1.52 | 0.50 | 1.00 | 2.00 |
| language at home | 7304 | 2.61 | 0.80 | 1.00 | 4.00 |
| number of books | 7304 | 1.95 | 1.07 | 1.00 | 5.00 |
| mother's education | 7304 | 2.05 | 1.25 | 1.00 | 7.00 |
| father's education | 7304 | 2.48 | 1.53 | 1.00 | 7.00 |
| educational aspiration | 7304 | 4.81 | 1.34 | 1.00 | 7.00 |
| home possessions | 7304 | 12.34 | 2.00 | 8.00 | 16.00 |
| self-confidence | 7304 | 10.21 | 2.80 | 7.00 | 28.00 |
| value of mathematics | 7304 | 8.17 | 2.8 | 6.00 | 24.00 |
| perceived difficulty | 7304 | 9.90 | 2.50 | 6.00 | 24.00 |
| Home support | 7304 | 8.50 | 2.03 | 4.00 | 16.00 |
| students perception of school | 7304 | 3.80 | 1.63 | 3.00 | 12.00 |
| students safety in school | 7304 | 8.00 | 1.30 | 5.00 | 16.00 |
| frequency of homework | 7304 | 2.09 | 0.98 | 1.00 | 6.00 |
| time spent on homework | 7304 | 3.17 | 1.18 | 1.00 | 5.00 |
| TOTWGT | 7304 | 42.92 | 28.89 | 5.41 | 105.34 |
| PV_1 | 7304 | 335.90 | 85.22 | 54.42 | 655.73 |
| PV_2 | 7304 | 334.60 | 85.95 | 65.89 | 688.21 |
| PV_3 | 7304 | 332.38 | 86.67 | 57.38 | 710.75 |
| PV_4 | 7304 | 332.50 | 86.38 | 39.00 | 660.22 |
| PV_5 | 7304 | 334.01 | 85.89 | 50.16 | 729.66 |
| **TEACHER/PRINCIPAL LEVEL** | | | | | |
| MATWGT | 160 | 65.59 | 33.94 | 5.63 | 221.13 |
| teacher gender | 160 | 1.89 | 0.32 | 1.00 | 2.00 |
| teaching experience | 160 | 7.49 | 6.59 | 1.00 | 32.00 |
| teacher's formal education | 160 | 3.54 | 0.98 | 2.00 | 6.00 |
| mathematics major | 160 | 1.46 | 0.50 | 1.00 | 2.00 |
| science major | 160 | 1.62 | 0.49 | 1.00 | 2.00 |
| mathematics education | 160 | 1.53 | 0.50 | 1.00 | 2.00 |
| science education | 160 | 1.66 | 0.48 | 1.00 | 2.00 |
| education general | 160 | 1.46 | 0.50 | 1.00 | 2.00 |
| other | 160 | 1.59 | 0.49 | 1.00 | 2.00 |
| class size | 160 | 48.95 | 29.61 | 10.00 | 242.00 |
| class test | 160 | 1.16 | 0.42 | 1.00 | 3.00 |
| national test | 160 | 1.84 | 0.77 | 1.00 | 3.00 |

| | | | | | |
|---|---|---|---|---|---|
| testing frequency | 160 | 2.09 | 0.73 | 1.00 | 4.00 |
| recall questions | 160 | 1.43 | 0.53 | 1.00 | 3.00 |
| application questions | 160 | 1.29 | 0.50 | 1.00 | 3.00 |
| pattern & relationship quest | 160 | 1.78 | 0.47 | 1.00 | 3.00 |
| explanation questions | 160 | 1.73 | 0.53 | 1.00 | 3.00 |
| teacher's perception of school | 160 | 20.50 | 4.75 | 10.00 | 40.00 |
| teacher's safety in school | 160 | 7.03 | 2.15 | 3.00 | 12.00 |
| teacher's belief | 160 | 8.53 | 2.40 | 6.00 | 24.00 |
| limiting students factors | 160 | 16.80 | 3.25 | 9.00 | 25.00 |
| teacher's instructional practices | 160 | 19.89 | 4.44 | 11.00 | 33.00 |
| professional development | 160 | 9.50 | 2.00 | 6.00 | 12.00 |
| homework | 160 | 1.80 | 0.50 | 1.00 | 3.00 |
| opportunity to learn number | 160 | 6.61 | 1.79 | 5.00 | 15.00 |
| opportunity to learn algebra | 160 | 9.63 | 1.94 | 5.00 | 15.00 |
| opportunity to learn geometry | 160 | 13.51 | 2.66 | 6.00 | 18.00 |
| opportunity to learn data | 160 | 6.34 | 1.62 | 3.00 | 9.00 |
| ready to teach number | 160 | 9.74 | 1.82 | 5.00 | 20.00 |
| ready to teach algebra | 160 | 10.17 | 1.81 | 5.00 | 20.00 |
| ready to teach geometry | 160 | 12.28 | 2.90 | 6.00 | 24.00 |
| ready to teach data | 160 | 6.26 | 1.45 | 3.00 | 12.00 |
| school location | 160 | 3.29 | 1.24 | 1.00 | 5.00 |
| resources for maths | 160 | 25.50 | 8.20 | 12.00 | 42.00 |
| parental involvement | 160 | 6.30 | 1.15 | 5.00 | 10.00 |
| principal's perception of school | 160 | 20.76 | 3.99 | 10.00 | 32.00 |
| teacher's evaluation | 160 | 4.81 | 0.93 | 4.00 | 8.00 |

Table 2

*Student-level Predictors*

| | *B* | *S.E* | *t-ratio* | *p-value* |
|---|---|---|---|---|
| **student gender** | **18.26** | **2.12** | **8.61** | **0.000** |
| language at home | 0.78 | 1.26 | 0.62 | 0.543 |
| number of books | -1.29 | 1.55 | -0.83 | 0.438 |
| **mother's education** | **-1.58** | **0.75** | **-2.09** | **0.038** |
| father's education | 1.23 | 0.62 | 1.98 | 0.052 |
| **educational aspiration** | **7.33** | **1.21** | **6.05** | **0.001** |
| home possessions | 0.52 | 1.16 | 0.45 | 0.662 |
| **self-confidence** | **8.72** | **1.05** | **8.29** | **0.000** |
| **value of mathematics** | **10.76** | **1.42** | **7.56** | **0.000** |
| **perceived difficulty** | **-16.50** | **1.11** | **-14.81** | **0.000** |
| home support | 0.18 | 1.30 | 0.14 | 0.891 |
| **students perception of school** | **4.91** | **1.44** | **3.41** | **0.008** |
| **students safety in school** | **-4.34** | **1.23** | **-3.50** | **0.006** |
| **frequency of homework** | **3.26** | **1.22** | **2.68** | **0.019** |
| **time spent on homework** | **3.40** | **1.11** | **3.05** | **0.016** |

Table 3: *Teacher/Principal Predictors*

| | ***B*** | ***S.E*** | ***t-ratio*** | ***p-value*** |
|---|---|---|---|---|
| teacher gender | 6.97 | 13.02 | 0.54 | 0.593 |
| teaching experience | 0.10 | 0.71 | 0.14 | 0.887 |
| teacher's formal education | -1.06 | 4.31 | -0.25 | 0.806 |
| **mathematics major** | **39.14** | **9.33** | **4.20** | **0.000** |
| **science major** | **-11.36** | **3.99** | **-2.85** | **0.006** |
| mathematics education | 4.00 | 11.96 | 0.33 | 0.739 |
| science education | 10.85 | 13.03 | 0.83 | 0.407 |
| education general | 13.84 | 8.37 | 1.65 | 0.101 |
| other | -5.39 | 8.17 | -0.66 | 0.511 |
| class size | -0.17 | 0.18 | -0.91 | 0.365 |
| **class test** | **-24.37** | **10.38** | **-2.35** | **0.021** |
| national test | 5.20 | 5.60 | 0.93 | 0.355 |
| testing frequency | -6.15 | 5.24 | -1.17 | 0.243 |
| **recall questions** | **-24.36** | **7.41** | **-3.29** | **0.001** |
| application questions | 7.69 | 9.27 | 0.83 | 0.409 |
| pattern & relationship quest | 6.18 | 9.86 | 0.63 | 0.532 |
| explanation questions | -8.33 | 8.41 | -0.99 | 0.324 |
| teacher's perception of school | 1.95 | 1.04 | 1.87 | 0.064 |
| teacher's safety in school | 7.80 | 4.51 | 1.73 | 0.086 |
| teacher's belief | 2.79 | 1.93 | 1.44 | 0.153 |
| limiting students factors | -2.05 | 4.10 | -0.50 | 0.618 |
| teacher's instructional practices | 0.78 | 0.94 | 0.83 | 0.407 |
| professional development | -5.96 | 4.38 | -1.36 | 0.176 |
| homework | -8.07 | 7.80 | -1.03 | 0.303 |
| opportunity to learn number | -2.41 | 2.75 | -0.88 | 0.382 |
| opportunity to learn algebra | 1.18 | 2.59 | 0.46 | 0.649 |
| opportunity to learn geometry | -1.71 | 1.67 | -1.03 | 0.307 |
| opportunity to learn data | -0.17 | 2.76 | -0.06 | 0.950 |
| ready to teach number | 2.97 | 2.42 | 1.23 | 0.222 |
| ready to teach algebra | -2.48 | 3.25 | -0.76 | 0.447 |
| ready to teach geometry | -0.92 | 2.33 | -0.39 | 0.694 |
| ready to teach data | 2.81 | 4.08 | 0.69 | 0.492 |
| **school location** | **-12.80** | **3.60** | **-3.67** | **0.001** |
| resources for maths | -4.56 | 4.75 | -0.96 | 0.339 |
| parental involvement | -5.54 | 3.81 | -1.46 | 0.148 |
| principal's perception of school | 0.34 | 1.17 | 0.29 | 0.771 |
| teacher's evaluation | 1.90 | 4.30 | 0.44 | 0.660 |

Table 4: *Full model*

| | *B* | *S.E* | *t-ratio* | *p-value* |
|---|---|---|---|---|
| **student gender** | **18.42** | **2.11** | **8.71** | **0.000** |
| language at home | 0.79 | 1.26 | 0.63 | 0.537 |
| number of books | -1.35 | 1.55 | -0.87 | 0.419 |
| **mother's education** | **-1.63** | **0.75** | **-2.16** | **0.033** |
| father's education | 1.23 | 0.62 | 1.97 | 0.052 |
| **educational aspiration** | **7.35** | **1.21** | **6.01** | **0.001** |
| home possessions | 0.88 | 1.17 | 0.75 | 0.460 |
| **self-confidence** | **8.66** | **1.05** | **8.29** | **0.000** |
| **value of mathematics** | **10.78** | **1.42** | **7.61** | **0.000** |
| **perceived difficulty** | **-16.43** | **1.12** | **-14.73** | **0.000** |
| home support | 0.18 | 1.30 | 0.14 | 0.891 |
| **students perception of school** | **4.97** | **1.44** | **3.45** | **0.007** |
| **students safety in school** | **-4.35** | **1.24** | **-3.52** | **0.006** |
| **frequency of homework** | **3.30** | **1.22** | **2.70** | **0.016** |
| **time spent on homework** | **3.38** | **1.11** | **3.03** | **0.019** |
| **Teacher/Principal level** | | | | |
| teacher gender | 5.71 | 11.13 | 0.51 | 0.609 |
| teaching experience | 0.23 | 0.61 | 0.38 | 0.703 |
| teacher's formal education | -0.42 | 3.67 | -0.12 | 0.908 |
| **mathematics major** | **32.84** | **7.97** | **4.12** | **0.000** |
| **science major** | **-8.77** | **3.54** | **-2.48** | **0.017** |
| mathematics education | 4.77 | 10.26 | 0.47 | 0.642 |
| science education | 9.49 | 11.14 | 0.85 | 0.396 |
| education general | 10.97 | 7.12 | 1.54 | 0.126 |
| other | -4.93 | 6.98 | -0.71 | 0.481 |
| class size | -0.16 | 0.16 | -1.02 | 0.311 |
| **class test** | **-19.84** | **8.90** | **-2.23** | **0.028** |
| national test | 4.40 | 4.84 | 0.91 | 0.365 |
| testing frequency | -7.76 | 4.48 | -1.73 | 0.086 |
| **recall questions** | **-19.20** | **6.30** | **-3.04** | **0.003** |
| application questions | -8.38 | 8.00 | -1.05 | 0.297 |
| pattern & relationship quest | -4.44 | 8.42 | -0.53 | 0.599 |
| explanation questions | 6.42 | 7.21 | 0.89 | 0.376 |
| **teacher's perception of sch** | **1.98** | **0.92** | **2.15** | **0.033** |
| teacher's safety in school | -7.44 | 3.92 | -1.90 | 0.060 |
| teacher's belief | 3.09 | 1.66 | 1.86 | 0.065 |
| limiting students factors | -1.40 | 3.52 | -0.40 | 0.693 |
| teacher's instructional pract | 0.45 | 0.80 | 0.56 | 0.576 |

| | | | | |
|---|---|---|---|---|
| professional development | -6.31 | 3.77 | -1.68 | 0.096 |
| homework | -3.55 | 6.67 | -0.53 | 0.595 |
| opportunity to learn number | -2.86 | 2.37 | -1.21 | 0.230 |
| opportunity to learn algebra | 1.40 | 2.21 | 0.64 | 0.527 |
| opportunity to learn geometry | -1.23 | 1.43 | -0.86 | 0.390 |
| opportunity to learn data | 0.19 | 2.36 | 0.08 | 0.937 |
| ready to teach number | 1.02 | 2.08 | 0.49 | 0.623 |
| ready to teach algebra | -1.24 | 2.83 | -0.44 | 0.662 |
| ready to teach geometry | 0.04 | 1.99 | 0.02 | 0.984 |
| ready to teach data | 1.46 | 3.51 | 0.42 | 0.679 |
| **school location** | **-10.26** | **3.05** | **-3.36** | **0.001** |
| resources for maths | -5.19 | 4.08 | -1.27 | 0.207 |
| parental involvement | -1.95 | 3.24 | -0.60 | 0.549 |
| principal's perception of school | 0.03 | 1.00 | 0.03 | 0.980 |
| teacher's evaluation | 0.28 | 3.70 | 0.08 | 0.940 |