PREDICTION OF NATIONAL MATHEMATICS AND SCIENCE ACHIEVEMENT
BY SOCIOECONOMIC AND HEALTH FACTORS
WITH A FOCUS ON GHANA

by

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Dedication

This project is dedicated to my beloved mom, Hannah Plange, wife, Gladys Ehwiah Appoh, and my kids, Moses and Annabelle for their encouragements and prayers during my education.
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My gratitude is extended to the Almighty God for my very existence, His provision, strength, favor, and good health I have enjoyed to reach this far. My gratitude is also extended to my supervisor, Dr. Peter MacMillan, for his guidance, motivation, sacrifice, and immense help since the inception of this project to its completion. My indebtedness is expressed to my committee members Dr. Dennis Procter and Dr. Jalil Safaei Boroojeny for their constructive comments and suggestions.

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Lastly, I am most grateful to all my professors at UNBC for their impact made in my life for being their student.
Chapter One Introduction

The Trends in International Mathematics & Science Study (TIMSS) is an international research project which is conducted under the auspices of International Association for the Evaluation of Educational Achievement (IEA). This project is under the direction of TIMSS and the Progress in International Reading Literacy Study (PIRLS) (Olson, Martín, & Mullis, 2008). TIMSS began assessments in 1995, and has since continued with its assessment at 4-year intervals (1999, 2003, 2007, 2011). The 2015 report was not available at the time of this study. As part of the TIMSS' assessment, data are collected from participating countries; data sources range from students, teachers, and school principals, to make a comprehensive report on the participating countries. Additionally, the TIMSS' assessment is based on two subjects: Mathematics and Science, for grades four and eight only. Each TIMSS' report provides up-to-date trends of performances of countries for previous years of participating and makes constructive comparisons (Mullis, Martin, Foy, & Arora, 2012).

I initially observed in the TIMSS 2011 report that relatively wealthy countries have higher mean scores while countries with low Gross Domestic Product (GDP) or Gross National Income (GNI) have lower mean scores. For instance, Singapore and Japan with GNI per capita of $54,040,000 and $46,140,000 in 2013 respectively had mean scores of 611 and 570 in 2011 grade eight Mathematics; Morocco and Ghana, on the other hand, with GNI per capita in 2013 of $3,030,000 and $1,760,000 respectively, had mean scores of 371 and 331 in the same 2011 TIMSS report. In spite of noticing this apparent relationship, as an experienced classroom teacher, I immediately thought of within-education factors such as curriculum that could account for poor results of countries in TIMSS 2011 report. However, upon further reflection, it appears imperative to consider some health and economic factors that are more fundamental to children’s lives before issues such as curriculum, school resources, or teacher education are examined.
In my observation, the country with the lowest scores in the 2011 TIMSS report for grade eight Mathematics and Science as indicated is Ghana. This is of particular interest to me not because it is the country with the lowest scores but because Ghana is my country.

**The Position of the Researcher**

I am a professional Mathematics teacher who has taught the subject over a decade from grades seven to nine in Ghana. I have also taught most students on a part-time basis ranging from grades ten to twelve; prepared matured students (25 years and above who take university entrance exams in order to gain admission because of not meeting the basic requirements) on many occasions for both undergraduate and degree entrance examinations in Ghana. Furthermore, in recognition of my hard work, excellence, and dedication as a professional teacher, I was awarded a certificate for my contribution to Mathematics achievement during my teaching in Ghana. I have been a member of the Mathematics Association of Ghana (MAG) and have attended many workshops between 2002 and 2012. At the time of writing, I am a graduate student at University of Northern British Columbia in the Masters of Education, Multidisciplinary Leadership specialization as well as part-time Mathematics tutor to a grade twelve student in Prince George.

My intent is to contribute to the improvement of Ghana's Science and Mathematics achievements both at the national and the international levels. As part of my growing understanding of the role of leadership in education, I believe I should have a moral purpose and act on this purpose (Fullan, 2007; Kaser & Halbert, 2009). Therefore my moral purpose as an educator will be to use this study to contribute in a small way to promote a better life worldwide, and particularly in Ghana, and make Ghana a better place to dwell My specific purpose as an educational leader is to help improve academic performance of students in general.

More specifically, I will investigate Ghana's poor Mathematics and Science
achievements in TIMSS. In Ghana these subjects are two of the compulsory subjects that students must pass in order to gain admission into any Senior High School (SHS) or tertiary institution in Ghana. No matter how brilliant a student may be, his or her inability to pass Science and Mathematics at the end of Junior High School (JHS) puts his/her future at jeopardy. It is an undeniable fact that Mathematics and Science continue to be challenging for most students worldwide, of whom Ghanaian students and teachers are no exception (Ker, 2013). But considering the importance of Mathematics and Science as stated earlier, more effort and resources are required to address the poor performance in Ghana. Improvement in these areas would likely contribute to the improvement in national technological and scientific advancement in Ghana. There is therefore the need for researchers, policy makers, and educationists to understand the factors that contribute to poor Science and Mathematics achievements as knowledge in Science and Mathematics is considered as a driving force in global economic innovations. This study will help address the research gap in the examination of Mathematics and Science achievements as related to socioeconomic and health factors.

**Economic and Health Factors**

Income of a country, community, and individuals has been reported by past studies to have significant influence on health and educational status at the national, community and individual levels (World Health Organization, 2014; OECD, 2010; Hales, Howder-Chapman, Salmond, Woodword, & Mackenback, 1999). Inequality of income distributions within both poor and rich countries directly and indirectly influences the health of the people within the countries (Judge, Mulligan, & Benzoval, 1998). The issue of inequality of income distribution is more challenging in developing countries than in the developed or advanced countries (O'Hare, Makuta, Chiwaula, & Bar-Zeev, 2013). Moreover, Gross National Income
(GNI) per capita of a country has been reported to have direct influence on female literacy which also affects child mortality (WHO, 2014).

Although the level of infant mortality has generally decreased in most parts of the world in the past 20 years, mortality remains relatively high in the sub-Saharan Africa and South Asia countries which are known to be poor (O'Hare, Makuta, Chiwaula & Bar-Zeev, 2013). Developed countries and more equal societies have better health and low mortality than developing countries with less equal societies (Avendaro, 2012). In Ghana, child mortality rate (under-5 mortality rate) has decreased to 72 deaths per 1000 live births between 1998 and 2012. However, the growth rate of Ghanaian children is a problem because of poor nutritional status as a result of poverty among Ghana's populace (WHO, 2014). WHO (2014), reported that, 28% of Ghanaian children are stunted and 14% being underweight. Poor nutritional quality as a result of poverty of parents, directly or indirectly has inverse effect on the health and cognition/ability of the children in low income countries. In 2008, it was reported that only about 54.7% of births in Ghana are attended by skilled health workers. This is due to low density (0.974) of nurses and midwives per 1000 population in the country (WHO, 2014). Again, high health costs negatively affect families' access to proper health care. There is not much difference in the situation in Ghana and other developing countries.

There is evidence that, on average, students from households with high income perform better than those from families with low income and similar patterns and trends have been observed between rich and poor communities and countries (Ladd, 2012). This suggests that a country's GNI per capita may have influence on the standard of education in the country. Factors such as educational infrastructure, educational policies by government, and quality of teachers which are all income dependent, significantly affect the standard of education in both national and regional levels (Ladd, 2012; OECD, 2010). The results of the 2009 Program for International Student Assessment (PISA) in reading and mathematics
showed a strong positive correlation between the socio-economic backgrounds and school achievement. Generally, the effect of poor nutritional quality on the cognitive domain of children from low income households may affect the performance of the children at school (WHO, 2014).

The Purpose of the Study

The goal of this study is to examine Ghana's Mathematics and Science achievements in relation to other countries in the TIMSS report with purpose of providing insight into how this might be improved. Before I can begin my study, which is to be carried out in a north west Canadian university, I must provide the readers with an overview of Ghana's history and politics in order to better understand the context of the nature of the study and the performance of Ghana.

Historical Overview of Ghana's Political System

Ghana is a West African country which was formerly known as Gold Coast. Ghana's official language is English. It was the first country in sub-Saharan Africa to gain independence in 1957 from the British colonial rule through the efforts of Dr. Kwame Nkrumah and other political leaders. Ghana has ten administrative divisions, with Accra its capital city. It has a population of 26,327,649 with a land size of 227,533 square kilometers (Central Intelligence Agency World Factbook, 2015). Dr. Nkrumah later became the first president of Ghana but was overthrown through a coup led by Lt. Jerry John Rawlings who took power in 1981. Rawlings banned political parties from contesting elections until a new constitution and multi-party politics was restored in 1992. He was later democratically elected and governed Ghana for two terms from 1992-2000. President Rawlings' successor was President Kuffour who was also re-elected for a second term in 2004. President John Atta Mills then succeeded president Kuffour after the 2008 election but did not finish his first term in office due to his untimely death in July 2012. As enshrined by the constitution of Ghana,
the then vice president Mahama became Kuffour's successor to complete his term. President Mahama went on to win the presidential elections held in December, 2012; he is still the president till the end of 2016 at which time elections will again take place (UNICEF, 2013).

**System of governance.**

Ghana is a democratic republic where the president is both the head of state and the head of government within a multi-party system. The Flagstaff House is the official seat of government. The three arms of government consist of the executive, the legislative and the judiciary. The government exercises the executive power; the legislative power is vested in both the government and the parliament. The judiciary on the other hand consists of the Supreme Courts of Judicature and other Inferior Courts. The constitution of Ghana allows it to be a republic with sovereignty vested in Ghanaians. The 1992 constitution establishes power-sharing and prevents coups, dictatorial governments, and one party state rule. The British and American constitutions were used as models in drawing Ghana's constitution and the documents also reflect past experiences from the abrogated constitutions of 1957, 1960, 1969, and 1979. Above all, the constitution provides checks and balances, with the power shared among the president, the parliament, the council of state and the independent judiciary (CIA Factbook, 2015).

**Executive arm of government.**

The office of the president exercises the executive power with the help of the Council of State. The president is the Head of State, Head of Government, as well as the Commander in Chief of the Ghana Armed Forces. In accordance with the constitution, the president appoints the vice president, and he has a mandate to appoint more than half of his ministers from the parliament (CIA Factbook, 2015).

**Legislative arm of government.**

The legislative function is vested in parliament. This constitutes a 275-member body
in addition to the speaker. For a bill to become a law, the president has to approve except those bills that require a vote of urgency. The members of parliament are elected for a four-year term in single seat constituencies by a simple majority vote. Since 1992, elections have been held every four years in the same year as the presidential elections. Both presidential and parliamentary elections have been held on December 7. But with amendments made currently, subsequent elections will be held on November 7, beginning in 2016 to give the nation ample time to manage the transition between end of election and settling of government functionaries (CIA Factbook, 2015).

**Judicial arm of government.**

The judiciary, being independent, has a different structure and power from the other two arms of government. The Supreme Court of Ghana has the power of judicial review. The constitution empowers it to rule over the constitutionality of either legislative or executive actions of which any aggrieved citizen might seek. The hierarchy of the courts is derived mostly from the British judicial system. The Supreme Court of Ghana, the Court of Appeal, the High Court of Justice, and the ten Regional Tribunals form the judicial system. (CIA Factbook, 2015). These courts are listed in descending order of authority.

**Ghana's democracy as compared to neighboring countries.**

Ghana has been stable since the inception of the 1992 constitution. The democratic institutions such as the courts, Centre for Democratic Development (CDD), and Alliance for Accountable Governance (AFAG) have pressed home the provisions as enshrined in the constitution of Ghana in order to reflect the views and opinions of the citizenry (Keith, 2002). For instance, after 2008 general election, the Electoral Commission (EC) of Ghana declared His Excellency John Dramani Mahama of the National Democratic Party (NDC) the winner. The opposition, the New Patriotic Party (NPP), did not accept the EC's declaration and therefore sent their petition to the Supreme Court of Ghana. After months of court
deliberation, Mr. Mahama was confirmed the winner. Even though the court's decision to confirm His Excellency John Dramani Mahama as the president was not pleasing to some Ghanaians, they accepted the court's verdict because they believe in democracy and the rule of law. The religious leaders and groups have played important roles in the development of Ghana. For instance, the religious groups such as The Catholic Bishops Conference and the Christian Council of Ghana served as advocates during the military era. Okyerefo, Fiaveh, and Asante (2011) point out those religious groups in Ghana have also played a major role through peaceful messages in ensuring peaceful elections to reduce tensions that arise during election periods in the country. Ghana has enjoyed relative peace, religious tolerance, and existence of social support system. For example, disciplinary actions are sole responsibility of the society. This ensures that Ghanaians comply with social norms.

Unlike Ghana, some neighboring countries such as Cote d'Ivoire and Togo have experienced incidents of violence. While in Ghana peaceful demonstrations are used to drive home the opinions of the masses to the authorities, the same cannot be said of Cote d'Ivoire and Togo. Ethnic differences have torn most countries in West Africa apart without using legitimate channels to address certain issues.

As an example of these problems, Cote d'Ivoire, the former president, Mr. Laurent Gbagbo played the ethnic and tribal cards to disenfranchise Mr. Alhassan Ouattaran from contesting the presidential elections in 2010. This lead to ethnic animosity tendencies which ended up in the divisions that resulted in a civil war which eventually disorganized the country for some time until the return to democratic rule. Furthermore, the Cote d'Ivoire experienced post election violence in 2011 which led to a great setback in economic development. However, through prudent measures adopted by the current president Alhassan Ouatarra, Cote d'Ivoire is currently a country of envy in the West Africa (Mbeki, 2011).

In the case of Togo, most civil society groups and the opposition protested against the
existing voters' register. This led to an appeal which was sent to the then chairman of Economic Community of West African States (ECOWAS); this was the current president of Ghana, John Dramani Mahama. In his capacity as the ECOWAS president, he advised the Electoral Commission (EC) of Togo to correct the voters register. After the revision of the voters register, the incumbent president, Faure Gnassingbe won the election and as a result there is peace in the country.

A Brief Background of Ghana's Economy

Ghana's economy has had ups and downs for years but became stable, competitive, and attractive to foreign investment to the country in the era of President Kuffour. However, bad policies of government coupled with high budget deficit, as well as persistent depreciation of Ghana's currency have destabilized the economy. According to CIA (2015), agriculture accounts for 25% of Gross Domestic Product (GDP). This sector employs more than half of the country's labor force (CIA, 2015). Some of the main sources of foreign currency are gold, cocoa, and remittances from the Diaspora. Furthermore, Ghana experienced economic growth after the expansion of the oil field but could not sustain it due to recent drop in oil prices and economic mismanagement. The Atuabo gas plant is currently supplying natural gas to power thermal plants in the country as Ghana has recently experienced an unreliable power supply. This has adversely affected the general economic performance of the country.

Additionally, the Government of Ghana under the leadership of President Mahama signed a loan agreement of $920 million with International Monetary Fund (IMF) in April, 2015 to assist in curbing the economic hardship the country is currently facing. The conditions of loan from IMF require Ghana to minimize its fiscal deficit by lifting all kinds of waivers the government provides to Ghanaians, reduce bloated public sector wage bill, and intensifying revenue generation internally (CIA, 2015).
Poverty in Ghana.

Ghana is considered a developing nation, one that is seeking to become more advanced economically and socially (Oxford English Dictionary, 2004). The country is endowed with many natural resources such as gold, diamond, bauxite, manganese, rubber, cocoa, and recently oil (CIA, 2015). However, according to United Nations Children Education Fund (UNICEF, 2013), 54% of Ghanaians live on less than $2.00 (USD) a day. One out of four Ghanaian children lives in poverty. In 2010, the total number of poor people living in the rural areas was recorded as 4,637,373 (UNICEF, 2013). With this figure, it represents about 18% of the total population. UNICEF (2013) further reports that 60% of Ghanaians were unemployed. It therefore not surprising to note that between 2002 and 2010 there was 33.9% of children engaged in labor in the country.

Worldwide poverty is one of the issues of concern and Ghana is no exception to countries that is confronted with it (World Bank Group, 2014). Poverty serves a barrier to academic achievement because many factors can affect the development of an individual confronted with it. Such factors can be hunger, malnutrition, and diseases such as malaria and anemia. World Bank Group (2014) advocates that shared prosperity means there should be equal opportunities for all. In 2013, UNICEF reported that 57% of Ghanaian children were affected by malaria. Furthermore, poverty is also considered as a limitation in inclusive education (Noble, Norman, & Farah, 2005). This is because it deprives students from being actively involved in the activities of the school. Noble et al. (2005) further emphasize that students confronted with poverty have high stress levels which make them vulnerable when it comes to academic achievement. This eventually affects their language development and memory. Additionally, these children tend to disobey rules and are easily angered and are not sociable (Alaimo et al., 2001).

In order to reduce poverty, Ghana needs to improve in both Science and Mathematics
achievements so that more engineers could be trained to help refine most of raw natural resources such as gold, diamond, cocoa, and bauxite to get value for money. It is against this background that Mathematics and Science education will enhance Ghana technologically and enjoy the benefits that come with it. Ultimately, students or graduates from Ghana can be more competitive and recognized internationally due to innovations. This will go a long way to reduce poverty because with an increase in technology, there will be more industries to create jobs which will eventually reduce unemployment and make Ghana self sufficient in terms of agriculture which is the backbone of Ghana's economy. Also, with the help of technology Ghana can add more value to the mining sector by refining the Gold ores locally.

The Educational System in Ghana

The Ministry of Education (MoE) is mandated to see to it that all Ghanaians have relevant education at every level. The MoE is expected to ensure that Ghanaians have requisite skills to enable them to attain the full potential and be capable in the area of socio-economic growth so as to minimize poverty, and contribute their quota in developing their nation. To realize this mission, the MoE is expected to

- provide infrastructure to help all citizens to be literate and independent regardless of age, gender, tribe, religion, and any association that they might belong.
- ensure that everybody enjoys basic education.
- ensure equal educational access for all.
- educate and train Ghanaians to develop skills, placing emphasis on science, technology, and creativity.
- develop outermost manpower using higher education. (Ghana Education Service report, 2004).

As enshrined in the 1992 constitution of Ghana, all Ghanaians are empowered with the right to enjoy basic education. As spelt out in article 38 sub-section 2
The Government shall within two years after parliament first meet after coming into force this constitution draw up a program for the implementation within the following ten years for the provision of a free compulsory universal basic education”.

The Free Compulsory Universal Basic Education (Fcube) was launched in 1996 for a decade (1996-2005) to enable every child to be in school once the child reaches school age. The composition of pre-tertiary education in Ghana consists of: pre-school education (2 years), basic education - 6 years and 3 years in primary and junior secondary school respectively and senior secondary school (3 years). The rest are technical & vocational education (3 years), teacher education (3 years). There is also special education consisting of polytechnic education (3 years) and university education (4 years). (GES report, 2004).

Many international organizations assisted Ghana to make the Fcube program a reality through technology and financial aid: the Canadian International Development Agency (CIDA), the German Government through (KFW & GTZ), the Japan International Co-operation Agency (JICA), the World Bank through International Development Association, the European Union (EU) and the United States through (USAID). Others organizations are the United Kingdom through the Department For International Development (DFID), the United Nations Children Education Fund (UNICEF), United Nations Education, Science and Culture Organization (UNESCO), the United Nations Development Program, and UNDP, (Sekyere, 2012, pp. 117-118).

Public education funding and management.

The government of Ghana funds public education through budget allocation and support from donor agencies such as CIDA, JICA, UNECEF, and USAID. It is the responsibility of the ministry of education to oversee its management (Sekyere, 2012). Because of the many schools in Ghana, this process delays the disbursement of funds and supplies such as furniture, teaching and learning materials, and other logistics that promote
the teaching and learning process. At the JHS level, the government provides capitation grants to all schools to cater for children’s internal examination fees each term. This is because at the JHS level, each school conducts internal exams for each term until the third term. While in JHS three, every student takes external exams with results used for placement at the SHS level. Each student is responsible for paying the registration fees for the external examination. Considering the role the government plays in providing funds to conduct internal exams at each level, more often than not the monies are delayed and render these examination systems ineffective for many. Therefore if the government which is responsible to provide funding sometimes delay in releasing funds it affects everything and consequently affect students academic performance in the long round.

The condition of teachers.

Teachers play a vital role in preparing students to do well in their academic pursuit but if such teachers lack proper training, are not retained for long in their field, and are not well paid, this can greatly affect children’s performance. Teaching in Ghana is not a lucrative job and because of that most people use it as a stepping stone. It is common to see teachers leave the profession when they get a better job. When this happens, there is always lack of teachers to teach all the subjects, and even those who remain in the profession resort to rampant strike actions which eventually affect students’ performance. Considering the important role mathematics and science play in the technological advancement of a country and how students perceive the subjects to be hard, having a teacher who is not motivated puts students at jeopardy because some teachers have no passion for the job they are doing and this invariably affect the way he or she prepares the students for life, not just for exams. According to West Africa Examination Council (WAEC) Chief examiner’s report (2012), a lack of adequate exercises given to students and a lack of completion of syllabus account for some of the poor math performance among students. This is situation is bound to happen if
teachers are always going on strike in demand of better remuneration. The students' learning time lost by teachers in fighting for better conditions of service cannot be retrieved when strikes are ended. Education is the backbone of every nation's development, and therefore neglecting education is a sign of underdevelopment and obviously Ghana as a nation is not aiming at that. The fact that Ghana joined the TIMSS in itself is an indication that the country wants international recognition. Mullis et al. (2012) argue that teacher preparation and how satisfying they find their profession has a positive impact on Mathematics and Science achievement. Also, students who are privileged to be taught by more experienced and optimistic teachers have higher achievement in Mathematics and Science. Ker (2013) also suggests that in order to improve Mathematics there should be review in curriculum, methodology, as well as assessment. However, in Chapter Two, I suggest that curriculum is not the fundamental issue to consider in this study.
Chapter Two Literature Review

Trends in International Mathematics and Science Study (TIMSS)

I introduced briefly TIMSS in Chapter One. I expand on the study here in the preparation for my own study. The Trends in International Mathematics and Science Study (TIMSS) is an international research project which is conducted under the auspices of International Association for the Evaluation of Educational Achievement (IEA). The TIMSS began assessment in 1995, and has since continued with its assessment on a 4-year interval (1999, 2003, 2007, 2011, 2015). TIMSS' assessment is based on two subjects Mathematics and Science for grades four and eight only. Each TIMSS report provides up-to-date trends of performances of countries for previous years of participation and makes constructive comparisons (Mullis, Martin, Foy, & Arora, 2012).

Areas for TIMSS' Assessment

The TIMSS Mathematics and Science assessments use a comprehensive outline which was developed in conjunction with all the participating countries to assess curriculum content domains of: Number, Algebra, Geometry, and Data & Chance, for Mathematics with Biology, Chemistry, Physics, and Earth Science for Science. There are specified cognitive domains to advise teachers as to how students to be engaged when dealing with content areas (Mullis et al., 2012). For my study, only the Grade eight Mathematics and Science assessments are considered.

Table 1 gives a breakdown of domains of grade eight Mathematics. Note both content and cognitive domains are given.
Table 1

**TIMSS 2011 Grade Eight Math Assessment Framework**

<table>
<thead>
<tr>
<th>Content Domains</th>
<th>Cognitive Domains</th>
</tr>
</thead>
<tbody>
<tr>
<td>30% Number</td>
<td>40% Knowing</td>
</tr>
<tr>
<td>20% Algebra</td>
<td>40% Applying</td>
</tr>
<tr>
<td>20% Geometry</td>
<td>20% Reasoning</td>
</tr>
<tr>
<td>20% Data &amp; Chance</td>
<td></td>
</tr>
</tbody>
</table>

Source: TIMSS 2011 executive summary, p. 6

The Science Domains are presented in Table 2. Note there are slight differences in the cognitive domain proportions of Knowing, Applying, and Reasoning between Science and Mathematics frameworks.

Table 2

**TIMSS 2011 Grade Eight Science Assessment Framework**

<table>
<thead>
<tr>
<th>Content Domains</th>
<th>Cognitive Domains</th>
</tr>
</thead>
<tbody>
<tr>
<td>35% Biology</td>
<td>35% Knowing</td>
</tr>
<tr>
<td>20% Chemistry</td>
<td>35% Applying</td>
</tr>
<tr>
<td>25% Physics</td>
<td>30% Reasoning</td>
</tr>
<tr>
<td>20% Earth Science</td>
<td></td>
</tr>
</tbody>
</table>

Source: TIMSS 2011 executive summary, p. 6
Overview of TIMSS 2011 International Benchmark for Grade Eight

A score of 500 is the central benchmark; this has been constant for each assessment since TIMSS inception. While students' scores generally fall between 300 and 700, the TIMSS achievements scales has a possible range of 0-1000 for both grades Four and Eight. TIMSS sets other levels in the benchmarks: Advanced international benchmark (625), High international benchmark (550), Intermediate international benchmark (475), and Low international benchmark (400). These benchmarks values are the same for both Mathematics and Science.

Descriptors for benchmarks.

Descriptors for the International benchmarks for both Mathematics and Science at the grade eight level are as follows.

Mathematics

Advanced: Reason, draw conclusions, make generalizations, and solve linear equations.
High: Apply knowledge and understanding in a variety of relatively complex situations.
Intermediate: Apply basic knowledge in a variety of situations.
Low: Some basic knowledge of whole numbers and decimals, operations, and basic graphs.

(TIMSS 2011 executive report, p. 8)

Science

Advanced: Communicate an understanding of complex and abstract concepts in biology, chemistry, physics, and earth science.
High: Demonstrate understanding of concepts related to science cycles, system, and principles.
Intermediate: Apply understanding of science knowledge in various contexts.
Low: Recognize some basic facts from the life and physical sciences.

(TIMSS 2011 executive report, p. 8)
Impact of TIMSS on Participating Countries

The Organization for Economic Co-operation and Development (OECD, 2004) argues that when students excel in Mathematics this has the tendency to promote technological advancement and also encourage competitions among participating countries. This makes sense because as citizens become knowledgeable it boosts the countries workforce thereby moving the economy forward. This implies there will be an increase in production as a result of acquisition of knowledge. Also, the country is able to produce more engineers who will be capable of solving life issues that confront that particular country. In addition, advancement in technology has the tendency to reduce the cost of hiring technocrats from other countries, thereby promoting self-reliance on the citizens and promoting increased national high esteem.

TIMSS, being an internationally recognized assessment organization, provides an accepted picture of participating countries' strengths and weakness of Mathematics and Science. Policy makers of participating countries consider international reports such as TIMSS and Program for International Student Assessment (PISA) very important because it provides some useful information to them for reviewing their educational system (OECD, 2004). Similarly, OECD like TIMSS is also seen as credible, internationally recognized, and non-biased, stakeholders of education. Educationalists and academic stakeholders consider the recommendation of OECD's reports seriously to improve Mathematics education (OECD, 2004). TIMSS 2011 reports provide educational policymakers, administrators, teachers, as well as researchers with valuable insights functioning of educational systems of participating countries and constructive recommendations for educational research and how to improve them (Mullis et al., 2012). I see this as true because in life we tend to attach more importance to advice given by someone with integrity or in high authority than to advice of our colleagues or people with whom we are familiar. Even though the IEA team may point out our weakness in its report, we are not offended.
Ker (2013) also outlines some benefits TIMSS reports have on participating countries. Among them is the opportunity it offers educational stakeholders to see how their countries are doing internationally. For instance, in Ker's study, it was revealed that Singapore was successful in terms of Mathematics education when they were compared to equally high performing countries such as Chinese Taipei and America. Ker further emphasizes that Singapore had most students attaining higher percentage in Math achievement as compared to America and Chinese Taipei. For instance, while Singapore students had 47% for advanced 2011 TIMSS grade eight in the Advanced International benchmark, American students had only 7% of the same benchmark. Ker (2013) further explains that when majority of students are doing well in Mathematics as in the case of Singapore it implies to an extent that there is improvement in math education in their country.

**TIMSS scores for Developed and Developing Countries**

The world is changing rapidly due to science and technology. According to Trends in International Mathematics and Science Study (TIMSS, 2011) International Results in Mathematics for grade eight students, Ghana was found at the bottom with overall marks of 331 and a Standard error of 4.3 which is far below the TIMSS center benchmark of 500. Malaysia also recorded 440 with a standard error of 5.4 and Morocco also scoring 371 with a standard error of 2.0. (Low benchmark is 440). However, Korea and Singapore on other hand scored 613 (2.9) and 611 (3.8) respectively, which is well above TIMSS' "High" 550, benchmark of 550 for Mathematics grade eight students, (p. 6). Considering the statistics just cited, it is a matter of concern to educationalists or academic stakeholders, and makes it worth researching into the persistence poor performance of Ghana at the international level.

**The International Mathematics and Science Achievements of Ghana**

It has been established that any country that wants to advance technologically cannot do without taking Mathematics and Science education seriously (Ker, 2013). According to
West Africa Examination Council (WAEC, 2000), which is the external examining body for conducting examinations for all Junior High Schools (JHS) in Ghana, 53,735 out of 230,215 candidates had grades 1-6 in Mathematics, which means that 23% of students passed. The report argues that the performance of Science is similar to that of Mathematics. WAEC (2000) further explains that with 23% of passing rate, it implies that 176,480 students representing 77% of the candidates failed in Mathematics and Science.

Mathematics and Science are two of the core subjects that students are required to pass in order to gain admission into Senior High School in Ghana. Science and Mathematics study are indispensable in the twenty-first century. In this technological age, they play an important role in making the world easy to live. Furthermore, the importance of Mathematics and Science cannot be over-emphasized because neglecting them has adverse effects on productivity (Mullis, Martin, Foy, & Arora, 2012).

Mathematics is one subject that is required by students who have the interest of pursuing Engineering, Medicine, Nursing, Computing, and other areas that have to do with building a prosperous technological society. Before institutions admit any student to pursue any of the above programs, the students is required to have a sound background in Mathematics and Science in order to convince the institution that they would be capable of doing well in those programs. Most often students who have a desire to pursue such programs but who have a weak background in Mathematics and Science end up not getting admission into the program. Mathematics plays a vital role in daily activities. It is against this background that this study is intended to use health and economic data of countries and TIMSS 2011 data to predict success in Mathematics and Science achievement of Ghana in grade eight internationally.
Reasons for Ghana’s participation in TIMSS.

In pursuit of international recognition, Ghana has taken part in 2003, 2007, and 2011 in the Trends in International Mathematics and Science Study (TIMSS) conducted by the International Association for the Evaluation of Education Achievement (IEA) to assess the Science and Mathematics achievement of Junior High School students in more than sixty countries. Science and Mathematics are the two subjects that are considered the basis for technological advancement of any country (Anamuah-Mensah & Mereku, 2005). However, Mereku and Anumel (2011) report that Ghana placed 47th out of 48 countries in the TIMSS Math Achievement results conducted in 2003. Although Ghana's marks improved in TIMSS 2007, it was found at the bottom of 2011 TIMSS in grade eight. Ghana's marks earned both at the content domains and cognitive domains were far below the international average. This awful performance Ghana displayed at the international level leaves much to be desired.

Considering the importance Mathematics plays in the technological advancement of a country, it is imperative that Ghana improves on students' Mathematics and Science achievement. Ghana imports so many things that could be produced locally, and so advancing in terms of technology could help reduce its foreign debt, gain control over its economy, and provide better lives for its citizens. Nations that had similar economic and educational status at the time of Ghana’s independence – Singapore, Korea, Japan, and Malaysia – have all had higher achievement on the TIMSS-2003 (Amanuah-Mensah, Mereku, & Asabere-Ameyaw, 2004). The Mathematics and science achievement in these countries also reflects their superiority over Ghana in technology and overall prosperity. Furthermore, the usefulness of Mathematics cannot be overemphasized as economists rely on the subject in describing the world (Bishop, Clement, Keitel, Kilpatrick, & Leung, 2003).

As a Ghanaian Junior High School (JHS) Mathematics teacher, low academic performance of JHS and Senior High School (SHS) students in Mathematics in Ghana is a
concern to me personally as well as to other educationalists, and other stakeholders- because Mathematics and Science are among the four core subjects that students must pass at the JHS level in order to gain admission to SHS through the Computerized School Selection and Placement System (CSSPS). Students whose Mathematics achievement is strong enough to allow them access to SHS and further education can expect access to higher socio-economic status throughout their lives. Those who fail Mathematics and Science have fewer opportunities to improve their own living conditions and contribute to the health of their nation.

Possible reasons for Ghana's low achievement.

Mathematics and Science subjects must be passed before any students can gain admission to Senior High School (SHS), and Tertiary education in Ghana. Asante (1996) argues that when many students fail in an examination as in the case above, we either blame the students, the teachers, or both of them. We rarely question the validity of the exams or other factors. Asante maintains that if this happens then it implies the entire examination has failed us because the Junior High School (JHS) curriculum lacks clarity. He recommends that for purpose of assessment, the core curriculum at the JHS level should consist of knowledge and skills considered suitable with the range of low achievers. This makes sense because when a student is considered to fail in an examination it does not mean he or she did not gain any knowledge but there are numerous factors that can account that failure. Although Asante encourages me to infer that Ghana's persistent poor performance in grade eight Mathematics and Science achievement in TIMSS can be attributed to lack of clarity of TIMSS' assessments framework, I believe other factors might be of a higher priority.

According to Mullis et al, (2012, p. 18), students who exhibited higher Mathematics achievements had experienced and confident teachers than those with low Mathematics achievements. This implies that the issue of teacher quality has a role to play in Mathematics
and Science achievement. Therefore if Ghana wants to improve in TIMSS exams in future, those areas need to be looked at.

Again, other factors such as malnutrition can have a negative impact on educational achievement (Alaimo, Olson, & Frongillo, 2001). Alaimo et al. (2001) report that malnourished children from six years to eleven years have lower Mathematics achievement and also their likelihood of being repeated in class is very high. Also, teenagers with the issues of food insufficiency are likely to seek services of a psychologist because they tend to have difficulty living amicably with peers in the school setting. Such teenagers are also prone to suspension from school due to their behavior.

Curriculum.

Although every region in Ghana uses the same syllabus to teach all the subjects at the JHS level there can be wide variations in distribution of resources and implementation of the curriculum. Not all the regions use the same government books. Because the different books contain different ideas based on the level of experience of the authors, this makes it difficult to guarantee that all the students are adequately prepared to do well in external exams. Again, even the distribution of these textbooks is not done at the same time. A teacher would often find out that some regions will be using new textbooks while others will be using the old ones in anticipation of new ones. When this occurs it places the underprivileged regions at disadvantage because schools in those regions do not get their textbooks on time. This situation has the tendency to affect students' preparation towards external examination. Consequently, both teachers and students resort to cramming in an attempt to finish their syllabus in timely fashion which brings about poor performance.

What might be examined is whether or not the curriculum in Ghana is different from developed countries. However, casual comparison of British Columbia’s and Ghana’s
curricula as seen in Table 3 below suggests to me that exploring match curriculum in an attempt to identify Ghana's low Mathematics achievement is unlikely to be productive.

Table 3

A Comparison of BC and Ghana Grade Eight Curricula

<table>
<thead>
<tr>
<th>BC Grade eight curriculum</th>
<th>Ghana grades eight curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number</strong></td>
<td><strong>Number system</strong></td>
</tr>
<tr>
<td><strong>Pattern &amp; Relations</strong></td>
<td><strong>Mapping</strong></td>
</tr>
<tr>
<td><strong>Shape &amp; space</strong></td>
<td><strong>Shape &amp; space</strong></td>
</tr>
<tr>
<td><strong>Statistics &amp; probability</strong></td>
<td><strong>Statistics &amp; Probability</strong></td>
</tr>
</tbody>
</table>

sources: British Columbia Math syllabus, p. 16 and Ghana JHS Math syllabus, pp. 26-41

A cursory examination of British Columbia's, Ghana's curricula and that of TIMSS' assessment framework, suggest that curricula are roughly similar and yet there was a gross difference in performance between Ghana, BC, or other countries. Therefore examining curriculum is not a good starting point for this study. There might be more fundamental issues to be tackled in an attempt to investigate poor performance of Ghana in TIMSS. It will be difficult to find an antidote if Ghana needs to improve in future TIMSS. Fundamental issues such as GNI, Life expectancy, and child mortality must be considered first if Ghana has to make a head way in terms of participating in TIMSS.

In this study, the intent is to use the data presented in TIMSS 2011 table of grade eight Mathematics and Science achievement scores, along with economic and health data from the same countries that took part in the TIMSS 2011 study, and use multiple linear regressions to examine factors that can account for Ghana poor Mathematics and Science achievement in TIMSS study. This study will also be useful to the government of Ghana, stakeholders in education, teachers, and all those who value technology.
Method of Analysis

As I use a multiple regression in order to examine relationships between health and economic variables with Mathematics and with Science performance in TIMSS 2011 study, I am providing a brief review of linear regression. Chapter Three describes what was actually done rather than any description of the statistical technique.

Multiple linear regression.

Regression is the analysis of the relationship between two or more variables; one being dependent (criterion) and the others being independent (predictors). Regression analysis is a way of predicting an outcome variable using one or more predictor variables. The usefulness of regression cannot be over emphasized because often it is used to determine the strength of a relationship between independent and dependent variables (Field, 2009, p. 198). For the purpose of this study, multiple linear regression will be ideal to use because it has the ability to combine one dependent variable and several independent variables to assess a relationship. As with other correlation studies, statistical prediction does not imply causation; it may be necessary condition for it but it is a worthwhile first step.

The general equation for a multiple linear regression is:

\[ Y_i = (b_0 + b_1X_1 + b_2X_2 + \ldots \ldots + b_nX_n) + \epsilon_i \]

Where

\( Y \) and \( b_0 \) are dependent variable and intercept of the vertical line respectively. Also, \( b_1 \) and \( b_2 \) are coefficients of first and second predictors \( X_1 \) and \( X_2 \) respectively. \( b_n \) and \( \epsilon_i \) are coefficient of \( n \)th predictor \( (X_n) \) while \( \epsilon_i \) is the difference between the predicted and the observed valued of \( Y \) for the \( i \)th participant respectively (Field, 2009, p. 210).
Methods of regression.

Selection of predictors using multiple regression for a model, the researcher should be circumspect because the regression coefficient figures rely mainly on the model values (Field, 2009, p. 212). This implies that any error in the selection of predictors can affect the entire study and may render it the research worthless. Field (2009) further stresses that if predictors have no association, the sequence entry of their variable has negligible effect on parameters under consideration. However, in practice it is uncommon to encounter such a situation. He maintains that the mode of selecting a predictor cannot be over emphasized.

Hierarchical (block wise entry). In this type of method the researcher, the predictors of the study are chosen on account of past research and the decision of sequence in which predictors are entered are into the model lies with the researcher. More importantly, researcher should always enter predictors in the model considering their significance in predicting the outcome variable whether from past study before new predictors can be considered following the same rule.

Forced Entry. The method gives no room for the researcher to decide the order in which the predictors are entered in the model. All the variables for the study are entered at once in the model based on sound theoretical reasons as even exploratory. SPSS is a good example for using this type of approach. If the purpose of the study is aimed at testing theory, then this method is suitable (Studenmund & Cassidy, 1987).

Stepwise method. In this type of method, the sequence in predictors are chosen is controlled by mathematical criterion.

Research Questions

To achieve the purpose of my study, the following questions will be addressed:

- Do the variables of Gross National Income (GNI), under 5 mortality rate, and life expectancy adequately predict the TIMSS Science performance at the
country level of analysis with regards to the sub-areas of Science specifically Biology, Chemistry, Physics, and Earth Science?

- Do the variables of Gross National Income (GNI), under 5 mortality rate, and life expectancy adequately predict the TIMSS Mathematics performance at the country level of analysis with regards to the sub-areas of Mathematics specifically Number, Algebra, Geometry, and Data & Chance?

- Which countries among the 40 countries in the 2011 TIMSS report outperformed or underperformed based on the assumption that the factors of Gross national Income (GNI), under 5 mortality rate, and life expectancy have predictive power?

- Does the Mathematics and Science performance of Ghana stand out positively or negatively in relation to the prediction of Mathematics and Science performance by these predictors?

The Limitations of the Study

The 2011 TIMSS results contain Science and Mathematics scores for grades four and eight. However, for the purpose of this research, only grade eight Mathematics and Science will be considered and therefore the outcome of the study will be limited to only grade eight Mathematics and Science.

Additionally, there is the issue of sample not being known to be representative for countries. For poor countries, there might be groups of children who were not tested due to poverty leading to absenteeism. This subsequently leads to an unrepresentative sample. For instance, the number of students assessed in grade eight Mathematics for TIMSS' report ranged from 3,378 to 14,089 among countries (Mullis et al., 2012, p. 443). The difference in sample size can adversely affect the comparison of countries in this study.

The 2011 TIMSS report confirmed that there was a lack of clarity regarding the
curricula coverage for the grades although I am not exploring this within this study.
Chapter Three Method

Sample

The Mathematics and Science data for this study were taken from 40 countries who took part in 2011 TIMSS report (Mullis, et al., 2012). The health and economic data from the same countries are selected from the 2011 TIMSS from these sources: (UNESCO, 2015; World Bank Group, 2015; CIA World Factbook, 2015; UNICEF, 2011). The data will be based on overall Mathematics and Science achievements of only grade eight students of 40 countries who took part in the study. The average age of these students was 13.7 to 15.8 years (Mullis, Martin, Foy, & Arora, 2012, p. 450).

Procedure

I built one file with 40 countries taken from TIMSS 2011 international results in Mathematics and Science. Mathematics: Number, Algebra, Geometry, and Data & Chance were taken from Exhibit 3.2 pp. 144 and 145. Also, the Science: Biology, Chemistry, Physics, and Earth Science were taken from exhibit 3.2 pp. 146 and 147. The respective demographic and economic data chosen from the TIMSS 2011 were merged to produce one file in EXCEL which was then transformed to an SPSS data file. This allowed me to analyze both data sets using multiple regression in SPSS.

Analysis

Description of variables.

The following dependent (criterion) variables will be used for predicting independent (predictor) variables. Both criterion and predictor will be used instead of dependent and independent respectively throughout this project.

The criterion variables for total subsections for Mathematics are Number, Algebra, Geometry, and Data & Chance of national scores (Mullis et al., p. 307). Also, the criterion variables for total subsections for Science are Biology, Chemistry, Physics, and Earth Science.
Predictor variables.

Gross national income (GNI) according to World Bank 2016, is the sum of value added by all resident producers plus any product taxes (less subsides) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. The data of GNI was taken from World Bank Group, 2015.

Under five mortality (U5MR) is the combination of infant and child mortality and it is defined as the probability of dying between birth and exact age five. The rate is expressed per 1,000 children (Ghana Statistical Service, 2012, p. 174). The U5MR data was taken from CIA World Factbook, 2015.

Life expectancy (LE) according to World Bank (2016) indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. These data were taken from World Bank Group, 2015.

The TIMSS 2011 overall Mathematics and Science achievements of countries in grade eight namely Number, Algebra, Geometry, and Data & Chance (Mathematics), and Biology, Chemistry, Physics, and Earth Science (Science), were used as criterion variables while economic and health data such as life expectancy at birth, Gross National Income (GNI) per capita and mortality rate of the same countries were used as predictor variables. Microsoft EXCEL was initially used to manipulate countries in the TIMSS 2011 report alphabetically for easy identifications of countries. This is because the original table of the TIMSS 2011 was made based on countries’ performance in the study. Transferring sets of data from EXCEL into SPSS was easier and less time consuming. SPSS was used to perform the multiple regressions to ascertain which of the predictor variables can best predict poor Mathematics achievements in TIMSS 2011 report. Gu, Lai, & Ye (2011) confirm that if the
The purpose of the study is to predict academic achievement of which this research is no exception, then regression is suitable.

**Actual Analysis**

The following analyses were undertaken. Descriptive statistics for criterion variables, correlations for criterion variables for Mathematics and Science separately were calculated. Afterwards, I performed multiple regressions of Mathematics and Science to produce more descriptive statistics, correlations of all the variables entered, model summary, ANOVA, coefficients, collinearity diagnostics, casewise diagnostics, and residual statistics were calculated and examined. Additionally, histograms were used for Regression Standard Residual (RSR), Normal plot of RSR, as well as individual plots of criterion variable against each predictor variable are examined in order to examine the fit to the assumptions of linear regression. Also, a correlation matrix for all the individual variables for both Mathematics and Science area was analyzed to ascertain whether it would be useful to carry out multiple regression analyses with individual areas or whether a composite Mathematics variable, or composite Science variable might be used.

**Ethics-REB**

The data for this research were taken from international data out of text found in reports that are readily available to researchers and the general public, and as such no request for REB approval is needed.
Chapter Four Analysis

The first stage of this analysis is to establish the degree of correlation among the ten criterion variables for Mathematics (Number, Algebra, Geometry, Data and Chance) and Science (Biology, Physics, Chemistry, and Earth Science) plus two composite Mathematics and Science variables. The means, standard deviations, skews, as well as kurtosis for these variables, are presented in Table 4 while the correlations are placed in Table 5. Note that the mean and standard deviations for both are all similar across variables, between 457 to 476 for the means, and 59 to 81 for the standard deviations.

Table 4

Descriptive Statistics of Criterion Variables

<table>
<thead>
<tr>
<th>Math Score</th>
<th>Mean</th>
<th>SD</th>
<th>Skew</th>
<th>SE Skew</th>
<th>Kurtosis</th>
<th>SE Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math</td>
<td>465.20</td>
<td>65.74</td>
<td>.34</td>
<td>.37</td>
<td>-.05</td>
<td>.73</td>
</tr>
<tr>
<td>Num.</td>
<td>464.45</td>
<td>69.22</td>
<td>.20</td>
<td>.37</td>
<td>-.25</td>
<td>.73</td>
</tr>
<tr>
<td>Alg.</td>
<td>467.40</td>
<td>62.80</td>
<td>.54</td>
<td>.37</td>
<td>.23</td>
<td>.73</td>
</tr>
<tr>
<td>Geo.</td>
<td>459.78</td>
<td>67.93</td>
<td>.47</td>
<td>.37</td>
<td>.18</td>
<td>.73</td>
</tr>
<tr>
<td>Data</td>
<td>456.60</td>
<td>80.71</td>
<td>.11</td>
<td>.37</td>
<td>-.86</td>
<td>.73</td>
</tr>
<tr>
<td>Sci.</td>
<td>476.00</td>
<td>59.19</td>
<td>-.44</td>
<td>.37</td>
<td>.26</td>
<td>.73</td>
</tr>
<tr>
<td>Bio.</td>
<td>474.50</td>
<td>61.54</td>
<td>-.53</td>
<td>.37</td>
<td>.57</td>
<td>.73</td>
</tr>
<tr>
<td>Chem.</td>
<td>475.00</td>
<td>59.37</td>
<td>-.23</td>
<td>.37</td>
<td>-.45</td>
<td>.73</td>
</tr>
<tr>
<td>Phys.</td>
<td>472.85</td>
<td>62.65</td>
<td>-.46</td>
<td>.37</td>
<td>.65</td>
<td>.73</td>
</tr>
<tr>
<td>E. Sci.</td>
<td>473.05</td>
<td>65.99</td>
<td>-.77</td>
<td>.37</td>
<td>.89</td>
<td>.73</td>
</tr>
</tbody>
</table>

Note, Math = Mathematics composite score, Num., Alg., Geo., and Data represent Number, Algebra, Geometry, and Data & Chance respectively. Also, Sci. = Science composite score; Bio., Chem., Phys., and E. Sci. represent Biology, Chemistry, Physics, and Earth Science respectively.

Casual observation, that is noting similar means, similar standard deviations, and low standard deviations in comparison to means, does not suggest any extreme outliers; examination of skewness and kurtosis values indicate-no values beyond two standard errors so the distributions are all normally distributed.
Table 5

*Correlation between Pairs of the Potential Predictor Variables*

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Math</td>
<td>1</td>
<td>.99</td>
<td>.97</td>
<td>.98</td>
<td>.95</td>
<td>.91</td>
<td>.90</td>
<td>.91</td>
<td>.91</td>
<td>.83</td>
</tr>
<tr>
<td>Num.</td>
<td>.99</td>
<td>1</td>
<td>.94</td>
<td>.96</td>
<td>.95</td>
<td>.89</td>
<td>.89</td>
<td>.88</td>
<td>.83</td>
<td>.73</td>
</tr>
<tr>
<td>Alg.</td>
<td>.97</td>
<td>.94</td>
<td>1</td>
<td>.95</td>
<td>.86</td>
<td>.83</td>
<td>.82</td>
<td>.85</td>
<td>.73</td>
<td></td>
</tr>
<tr>
<td>Geo.</td>
<td>.98</td>
<td>.96</td>
<td>.95</td>
<td>1</td>
<td>.93</td>
<td>.90</td>
<td>.89</td>
<td>.91</td>
<td>.90</td>
<td>.82</td>
</tr>
<tr>
<td>Data</td>
<td>.95</td>
<td>.95</td>
<td>.86</td>
<td>.93</td>
<td>1</td>
<td>.94</td>
<td>.95</td>
<td>.92</td>
<td>.93</td>
<td>.91</td>
</tr>
<tr>
<td>Sci.</td>
<td>.91</td>
<td>.89</td>
<td>.83</td>
<td>.90</td>
<td>.94</td>
<td>1</td>
<td>.99</td>
<td>.98</td>
<td>.99</td>
<td>.98</td>
</tr>
<tr>
<td>Bio.</td>
<td>.90</td>
<td>.89</td>
<td>.82</td>
<td>.89</td>
<td>.95</td>
<td>.99</td>
<td>1</td>
<td>.96</td>
<td>.98</td>
<td>.97</td>
</tr>
<tr>
<td>Chem.</td>
<td>.91</td>
<td>.89</td>
<td>.86</td>
<td>.91</td>
<td>.92</td>
<td>.98</td>
<td>.96</td>
<td>1</td>
<td>.97</td>
<td>.93</td>
</tr>
<tr>
<td>Phys.</td>
<td>.91</td>
<td>.88</td>
<td>.85</td>
<td>.90</td>
<td>.93</td>
<td>.99</td>
<td>.98</td>
<td>.97</td>
<td>1</td>
<td>.95</td>
</tr>
<tr>
<td>E. Sci.</td>
<td>.83</td>
<td>.83</td>
<td>.73</td>
<td>.82</td>
<td>.91</td>
<td>.98</td>
<td>.97</td>
<td>.93</td>
<td>.95</td>
<td>1</td>
</tr>
</tbody>
</table>

Note, all correlations significant at \(p < .01\).

Examination of Table 5 reveals that the correlations between ten predictor variables for both disciplines were all very high. For instance, the correlation between Biology and Algebra was .8 and highest correlation being .9. Careful observation from correlation Table 5, suggests that each area of the two disciplines Mathematics and Science have high correlations within themselves, approximately .9. Therefore composite scores, that is, only one composite Mathematics and one composite Science score will be appropriate for the regression analysis. Repeated regression analysis with each subject area would not likely produce any different result due to high correlations displayed in Table 5. Note as well the Mathematics and Science areas also correlated strongly, again approximately .8 - .9 so although Mathematics and Science analyses will be carried out, results are expected to be very similar. The composite Mathematics score and composite Science score have a correlation of .91, again similar results are expected.

Consequently, the following decisions were taken, that there will be no multivariate analysis because correlation between Mathematics and Science was much higher than the typical .3 to .6 values that lead to successful and more sensitive multivariate analysis using one
combined Mathematics-Science variable. Only two linear regression analyses will be performed; one for composite Mathematics variable and the one for the composite Science variable as the predictor variable.

**Analysis of Science**

The Science regression results are now presented. These are followed by the Mathematics results. Table 6 shows the descriptive statistics of the three predictor variables (Under 5 Mortality Rate, GNI per capita, and Life expectancy). The composite Science score (criterion variable) statistics are in Table 8. Note again, there are only 40 countries participating in this particular study.

Table 6

*Descriptive Statistics of Criterion and Predictor Variables*

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Skew</th>
<th>SE Skew</th>
<th>Kurtosis</th>
<th>SE Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI</td>
<td>476.00</td>
<td>59.19</td>
<td>-.44</td>
<td>.37</td>
<td>.26</td>
<td>.73</td>
</tr>
<tr>
<td>U5MR</td>
<td>30.16</td>
<td>26.60</td>
<td>3.961</td>
<td>.37</td>
<td>19.65</td>
<td>.73</td>
</tr>
<tr>
<td>GNI</td>
<td>26256.81</td>
<td>24267.67</td>
<td>1.296</td>
<td>.37</td>
<td>1.52</td>
<td>.73</td>
</tr>
<tr>
<td>LE</td>
<td>76.48</td>
<td>5.03</td>
<td>-.848</td>
<td>.37</td>
<td>.85</td>
<td>.73</td>
</tr>
</tbody>
</table>

Note: SE = Standard Error, SD = Standard Deviation

From Table 6, I observed that two of the predictor variables have possible outliers. They are U5MR with a mean of nearly 30 and a standard deviation of nearly 27, and GNI per capita having a mean of $26,257 and a standard deviation of $24,268. Standard deviations showed a large spread in relation to its corresponding means. A standard deviation as large as the mean value indicates that at least some variables' values are very different than other values.

Table 7 shows the correlation of composite Science criterion variable and the three predictor variables.
The Science composite score is moderately or strongly correlated with each of the three predictor variables: Under Five Mortality Rate, -.72 – Cohen effect size large; Gross National Income per capita, .43 – moderate; and Life expectancy at Birth, .57 – large. Note all correlations are statistically significant, \( p < .005 \). A correlational relationship between any criterion variable and any predictor variable is necessary if the predictor has the possibility of being predictive within the linear regression.

I chose to proceed with the interpretation of the regression without investigation of possible outliers. A further regression analysis following investigation and removal of outliers was then performed. For this first regression involving Science with the three predictor variables there was a substantial relationship, \( R = .718 \), adjusted \( R \) square = .475. This indicates that 48% of the variation in the Science score can be explained by a linear combination of U5MR, GNI, and LE. This regression relationship was statistically significant, \( F (3, 36) = 12.78 \) \( p < .005 \). Table 8 gives the model coefficients of the predictor variables.

<table>
<thead>
<tr>
<th></th>
<th>SCI</th>
<th>U5MR</th>
<th>GNI</th>
<th>LE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI</td>
<td>1.00</td>
<td>-.72</td>
<td>.43</td>
<td>.57</td>
</tr>
<tr>
<td>U5MR</td>
<td>-.72</td>
<td>1.00</td>
<td>-.57</td>
<td>-.74</td>
</tr>
<tr>
<td>GNI</td>
<td>.43</td>
<td>-.57</td>
<td>1.00</td>
<td>.66</td>
</tr>
<tr>
<td>LE</td>
<td>.57</td>
<td>-.74</td>
<td>.66</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note, \( df = 38 \); all \( p < .005 \) (1 tailed)
Table 8

Coefficients of the Predictor Variables with Science as a Criterion Variable

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>432.85</td>
<td>176.14</td>
<td>2.46</td>
<td>.019</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U5RM</td>
<td>-1.43</td>
<td>.39</td>
<td>-.64</td>
<td>3.68</td>
<td>.001</td>
<td>.44</td>
<td>2.26</td>
</tr>
<tr>
<td>GNI</td>
<td>.00</td>
<td>.00</td>
<td>.01</td>
<td>.03</td>
<td>.977</td>
<td>.55</td>
<td>1.83</td>
</tr>
<tr>
<td>LE</td>
<td>1.12</td>
<td>2.26</td>
<td>.10</td>
<td>.50</td>
<td>.622</td>
<td>.37</td>
<td>2.74</td>
</tr>
</tbody>
</table>

From Table 8, only U5MR is statistically significant, p = .001 and having a beta coefficient of -.64 while GNI and LE beta coefficients were near zero and not statistically significant, p > .05. The t values ranges from .03 to 3.7. While multicollinearity was not expected due to moderate correlations among the predictor variables, collinearity indices were examined. Generally tolerance level must be greater than .2 and VIF must also be less than 4 in order to meet this assumption. Again with VIF levels less than 4 and tolerance greater than .2, well within acceptable ranges, no multicollinearity is judged to be present.

Assumptions for linear regression were checked, first normality of Science score was examined. A histogram of the composite Science score can be seen in Figure 1.
Figure 1. Histogram showing the distribution of regression standard residual of science criterion variable.

Furthermore, linearity was also checked examining the correlation plots of the three predictor variables; substantial linear relationships were found for all cases. No evidence of serious violations of homoscedasticity was found.

Decisions to Remove Large Outliers

From Table 9, U5MR is the only predictor with a high skew of 3.96 and a corresponding kurtosis of 19.65. The GNI variable was likely to have some possible outliers due to its large standard deviation relative to the mean.

Figure 2 presents the two GNI outliers in the bottom right hand corner of the graph.
Figure 2. A graph showing linear relationship between composite mathematics score and GNI.

To remove the two outliers, GNI values less than $80,000 was used as a condition for remaining in the regression analysis producing a sample of 38 countries.

There was one outlier for U5MR; it was Ghana. This outlier was retained because Ghana is a country of special interest in this study.

Although Ghana was retained because of being the country of special interest, analyses were done with Ghana removed and the results were compared. There were no differences of size or statistical significance. Therefore interpretation of only the analyses with two GNI outliers (N = 38) is presented.
**Outlier Analysis of Science and Mathematics**

There was no significant change in the results from the 40 country analysis to the 38 country analysis. With the removal of two cases in the model, there moderate correlations ranging from .6 to .7. Furthermore, with an $R = .765$ with adjusted $R$ squared = .549, this gives a percentage of 55% as against 48% variance explained recorded earlier on with all 40 cases and all the three predictors. So, the 55% of the model can be still explained by GNI and U5MR. The new $F (3,34) = 16.00, p < .005$ was essentially the same results as the 40 country analysis. With further analysis performed with N =37 (Ghana removed), $R = .699$, and the adjusted $R$ square came to .442, $F (3,33) = 10.51, p < .005$; again with a statistical significance This indicates that the model accounts for 44% of the variation in the Science achievement. Both U5MR and GNI were still found to explain Science scores. All assumptions for normality, collinearity, and linearity were checked but the graph is not shown because they are similar. Although Ghana could have been removed due to its extremely high U5MR value, it was ultimately retained because it is the country of special interest in this study and its removal did not alter the interpretation found in the 38 country (Ghana included) sample.

**Science Analysis with the 38 Country Sample**

From Table 9, with sample size of 38, only U5MR is statistically significant, $p = .001$ and having beta coefficients of -.59 and .30 respectively while the LE beta coefficient was near 0 and not statistically significant, $p > .05$. Note GNI is statistically significant only at the $p < .10$ level. The t values range from -3.52 to 1.78. Again, with tolerance levels less than 4 and VIF greater than .2, which are within range, no multicollinearity is judged to be present.
Table 9

Coefficients of the Predictor Variables with Science as a Criterion Variable

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>5544.82</td>
<td>171.19</td>
<td>3.18</td>
<td>.003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U5MR</td>
<td>-1.30</td>
<td>.40</td>
<td>-.59</td>
<td>-3.52</td>
<td>.001</td>
<td>.44</td>
<td>2.27</td>
</tr>
<tr>
<td>GNI</td>
<td>.00</td>
<td>.00</td>
<td>.30</td>
<td>1.78</td>
<td>.084</td>
<td>.44</td>
<td>2.27</td>
</tr>
<tr>
<td>LE</td>
<td>-.64</td>
<td>2.23</td>
<td>-.05</td>
<td>-.29</td>
<td>.775</td>
<td>.34</td>
<td>2.93</td>
</tr>
</tbody>
</table>

Analysis of Mathematics

As mentioned in the beginning of the analysis, due to high correlations among the dependent variables in table 5, I expected the Mathematics results to be similar to the Science. I present the Mathematics results in a more abbreviated form but where necessary I will support the presentation of the analysis with either a graph or a table. Also, the only Mathematics results presented are based on N = 38.

The means and standard deviations of the Mathematics composite scores were very similar to those reported in Table 6. The Mathematics composite score is moderately or strongly correlated with each of the three predictor variables: Under Five Mortality Rate, -.67 – Cohen effect size large; Gross National Income per capita, .61 – large; and Life expectancy at Birth, .56 – large. Note all correlations are statistically significant, p < .005. It was noted that all the three predictor variables correlations were slightly lower than the Mathematics composite score, the however the effect size remained the same as compared to the Science.

Next, histogram of the Mathematics composite score is presented in Figure 3.
Figure 3. Histogram showing the distribution of regression standard residual of mathematics criterion variable.

The Mathematics variable is normally distributed and other linear regression assumptions were judged to be met as well.

The regression of Mathematics composite with the three predictor variables yielded an $R = .713$ with an adjusted $R$ square $= .465$. This indicates that 47% of the variation in the Mathematics score can be explained by a linear combination of U5MR, GNI, and LE. The regression relationship was statistically significant, $F(3,34) = 11.71$, $p < .005$. The descriptive statistics of Mathematics composite variable and the predictor variables are presented in Table 10.
Table 10

**Coefficients of the Predictor Variables with Mathematics as a Criterion Variable**

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>529.52</td>
<td>207.90</td>
<td>2.55</td>
<td>.016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U5RM</td>
<td>-1.22</td>
<td>.45</td>
<td>-.49</td>
<td>-2.72</td>
<td>.010</td>
<td>.44</td>
<td>2.27</td>
</tr>
<tr>
<td>GNI</td>
<td>.00</td>
<td>.00</td>
<td>.34</td>
<td>1.86</td>
<td>.073</td>
<td>.44</td>
<td>2.27</td>
</tr>
<tr>
<td>LE</td>
<td>-.69</td>
<td>2.71</td>
<td>-.25</td>
<td>-.25</td>
<td>.801</td>
<td>.32</td>
<td>2.93</td>
</tr>
</tbody>
</table>

From Table 10, the beta values range from -.49 to .34 with t values from -.27 to -2.72 within the predictor variables. The predictor U5MR was statistically significant, p = .01. The GNI predictor in both Science and Mathematics was statistically significant but only at p < .10 level. Tolerance levels are less than .2 for all the three variables and again, all the VIF were also less than 4. Therefore multicollinearity is not evident in this analysis.

**Using Regression Outliers to Examine Aberrant Performance**

The aberrant achievements of countries in the regression analyses with outlier z scores > 2 as the criterion are presented in Table 11.

Table 11

**Aberrant Achievements of Countries in the Regression Analyses**

<table>
<thead>
<tr>
<th>Case Num</th>
<th>Country</th>
<th>C. Variable</th>
<th>Scores</th>
<th>SD</th>
<th>Pred.Value</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Macedonia</td>
<td>Science</td>
<td>407.0</td>
<td>-2.35</td>
<td>501.70</td>
<td>-94.70</td>
</tr>
<tr>
<td>19</td>
<td>Korea Rep.</td>
<td>Mathematics</td>
<td>613.0</td>
<td>2.40</td>
<td>495.84</td>
<td>117.16</td>
</tr>
</tbody>
</table>

Note Num = Number, C. Variable = Criterion Variable, Pred. Value = Predicted value
From Table 11, the two countries were Korea Republic and Macedonia respectively. While Korea was predicted to score 496 in Mathematics, Macedonia was also projected to score 502 in Science. While Korea scored higher than expected in Mathematics, Macedonian scored lower than expected in Science. Of note, Ghana, the country of special interest in this study performed according to expectations in these regression analyses. That is, these predictor variables adequately explain Ghana's performance.

Summary of Results

It was expected that after results of the regression analysis both Mathematics and Science will be similar but with the two variables removed, the adjusted R square appreciated to 55%. Science was seen as slightly more effective in the prediction even though both subjects had high R square values. For both Science and Mathematics, U5MR (p < .05) and GNI (p < .10) were factors when Ghana was removed. The adjusted R square was only 47% as compared to 55% with N=38. However, again Korea Republic over-performed in Mathematics achievement, and Macedonia again underperformed in Science achievement.

Overall, U5MR and GNI account for about 55% for overall Mathematics and Science achievement variations. However, Life expectancy had no substantial impact in predicting Mathematics and Science achievements with this combination of predictors. Comparing the model summary for both criterion variables, it was found that Mathematics criterion variable had lower slightly lower R square values as compared to Science; the adjusted R square in Science was .55, that of Mathematics was .47; indicating 8% difference. Although not tested, I believe an 8% difference between Science and Mathematics achievements would not be statistically significant. Therefore there is insufficient evidence to claim that Science achievement was higher than Mathematics.
Chapter Five Discussion

In the analysis of TIMSS 2011 Science and Mathematics data, I made a decision to use only thirty-eight (38) countries eliminating two countries for the study due to extreme values on the GNI variable. Ghana was retained in the analysis in spite of the extreme value on the U5MR. The research questions for the study are given with their corresponding results. In this chapter, I intend to provide each research question and answer them accordingly.

Science Achievement at Grade Eight Level

- Do the variables of Gross National Income (GNI), infant mortality rate, and life expectancy adequately predict the TIMSS Science performance at the country level of analysis with regards to the sub-areas of Science specifically Biology, Chemistry, Physics, and Earth Science?

Only a measure of child mortality (under 5 years) was important predictor in Science achievement at the grade eight level, but a measure of relative wealth of countries (GNI per capita) was statistically significant at \( p < .10 \) level. However, life expectancy was not a predictor of Science achievement at the same grade. These two variables accounted for 55% of the Science achievement variation.

Mathematics Achievement at Grade Eight Level

- Do the variables of Gross National Income (GNI), Under 5 mortality rate, and life expectancy adequately predict the TIMSS Mathematics performance at the country level of analysis with regards to the sub-areas of Mathematics specifically Number, Algebra, Geometry, and Data & Chance?

Only a measure of child mortality (under 5 years) was important predictor in Mathematics achievement at the grade eight level, but a measure of relative wealth of countries (GNI per capita) was statistically significant at \( p < .10 \) level. However, life expectancy was not a predictor of Mathematics achievement at the same grade.
These two variables accounted for 47% of the Mathematics achievement variation.

**Performance of Countries for both Science and Mathematics**

- Which countries among the 40 countries in the 2011 TIMSS report outperformed or underperformed based on the assumption that the factors of Gross national Income (GNI), infant mortality rate, and life expectancy have predictive power?

Korea Republic outperformed in Mathematics achievement, however, Macedonia underperformed in Science achievement.

- Does the Mathematics and Science performance of Ghana stand out positively or negatively in relation to the prediction of Mathematics and Science performance by these predictors?

In spite of being the lowest performer in both Mathematics and Science, Ghana's position among the forty (40) countries used for this study is well explained by these variables of GNI, U5MR, and LE. A measure such as GNI has impact on countries educational achievement (Ladd, 2012; OECD, 2010) and Ghana has performed as expected.

**Implications for Practice**

From the results, Ghana needs to focus more on the issues of child health if it wants to develop the intellectuals needed. Child health must be tackled as a matter of urgency. As reported earlier in the literature, poor nutrition affects the health and cognitive of students in low income countries, of which Ghana is no exception (WHO, 2014). These factors likely overshadow possible differences curriculum delivery, teacher quality, or curriculum fit with that of developed nations. Also, other countries should take heed that at all level of education, academic success is linked to these measures and health of young children is a concern for even the wealthiest countries as well.
Future Research

Future studies should be undertaken with the intent of establishing causation. For Mathematics, the 2011 TIMSS report shows that 12 countries improved. Some of these countries were Singapore, Korea, and Hong Kong SAR. East Asian countries were considered as top performing. In the case of Science, 8 countries showed improvement and only one declining. Hong Kong SAR, Hungary, Iran, Japan, and Korea were some of the countries that improved. Norway was the only country that declined. Changes in economic and social factors might be investigated to establish whether these changes can be linked to TIMMS achievement changes. This would be a first step in establishing cause. Examination of curriculum match/mismatch literature should also be done to rule out or alternatively establish this source of TIMSS achievement.

As Ghana is of particular interest, investigation of performance difference by regions should be done with socioeconomic factors being considered. Any differential change in these regions’ economical conditions should be examined in relation to TIMSS or other standardized achievement. Finally, suggestions of variation in the quality of instruction should be examined in order to establish whether this is indeed a factor that contributes to Ghana’s performance. However, using more immediate determinants such as nutrition, female literacy, and amenities are better justified than distal factors such as GNI, USMR, or LE.
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