WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

BRAIN HEMISPHERICITY AND MATHEMATICS ACHIEVEMENT OF HIGH SCHOOL STUDENTS

A Thesis Presented to the

Faculty of the Graduate School

College of Education

West Visayas State University

La Paz, Iloilo City

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts in Education

(Secondary Mathematics)

by

Sanny Francisco Fernandez

October 2011

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COLLEGE OF EDUCATION
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A Thesis for the Degree

Master of Arts in Education

(Secondary Mathematics)

by

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Abstract

This study aimed to find out the brain hemisphericity and mathematics achievement of high school students. The respondents of the study were the 168 first year high school students of Colegio de San Jose, during school year 2010-2011who were chosen through stratified random sampling. The descriptive and interview methods of research were used in this study. To determine the students' brain hemisphericity, a Hemisphere Dominance Questionnaire was employed, while the Mathematics Achievement Test was utilized to find out their mathematics achievement. IQ results were taken from the guidance center and interviews were conducted. Frequency count, mean, and standard deviation were the descriptive statistics utilized while Chi-square and ANOVA were the inferential statistics employed. The results revealed that whether taken as an entire group or classified according to gender and intelligence quotient, the dominant brain hemisphericity of the students was the left brain. Their mathematics achievement when taken as an entire group and classified as to gender, intelligence quotient, and brain hemisphericity was "average". No significant difference existed in the dominant brain hemisphericity of students when classified as to gender and intelligence quotient. Similarly, no significant difference existed in their

mathematics achievement when classified according to brain hemisphericity. In solving mathematical problems, the left- brain students tend to write an equation and make logical explanation while the right-brain students tend to make diagrams and illustrations. It was found out in the interview that students tried their best to answer the given problem; however, only very few completed the solution due to several difficulties they encountered.

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Brain Hemisphericity and Mathematics Achievement

of High School Students

Sanny F. Fernandez

Chapter 1

Introduction to the Study

Chapter 1 is made up of five parts: (1) Background and Theoretical Framework of the Study, (2) Statement of the Problem and the Hypotheses, (3) Significance of the Study, (4) Definition of Terms, and (5) Delimitation of the Study.

Part One, Background and Theoretical Framework of the Study, presents the underlying reasons for conducting the research and the framework that served as basis and support for the study.

Part Two, Statement of the Problem and the Hypotheses, states the general and specific problems as well as the hypotheses tested.

Part Three, Significance of the Study, describes the stakeholders of the research and the manner by which they may be able to benefit from the results.

Part Four, Definition of Terms, defines conceptually and operationally the important terms and the key variables used in the study.

Part Five, Delimitation of the Study, sets the limits of the research in terms of the respondents, research design, variables, research instrument, and statistical tools.

Background and Theoretical Framework of the Study

The brain is the most important part of the human anatomy. It tells all the other parts what to do, and when to do it. The brain works as part of a network that includes the spinal cord and peripheral nerves. Together, they transmit and control any information sent to and from the other areas of the body. Nonetheless, the brain is the master controller (Jeanty, 2008).

Fifty to one hundred billion nerve cells or neurons that remain in constant interaction with one another make up the human brain, making it one of the most complex human organs. The constantly connected neurons relay messages through electrochemical processes. Chemicals in the body move in and out of cells, establishing an electrical current that tells the body what to do. Each message is sent to either the left or right part of the brain in order to carry out the proper function (Pena, 1998).

The concept of right brain and left brain thinking was developed from the research in the late 1960s of an American psychobiologist, Roger W. Sperry. He discovered that the human brain has two very different ways of thinking. Similarly, Evans (2010) mentioned that the right brain / left brain theory emphasizes that the brain has two hemispheres (commonly called the right brain and the left brain) which think in different ways. One (the right brain) is visual and processes information in an intuitive and simultaneous way, looking first at the whole picture then the details. The other (the left brain) is verbal and processes information in an analytical and sequential way, looking first at the pieces then putting them together to get the whole.

Brain hemisphericity is the tendency of an individual to process information through the left hemisphere or the right hemisphere or in combination (Bradshaw & Nettleton, 1981; McCarthy, 1996; Springer & Deutsch, 1993). Research has demonstrated that the left hemisphere operates in a linear, sequential manner with logical, analytical, propositional thought. On the other hand, the right hemisphere operates in a nonlinear, simultaneous fashion and deals with non-verbal information as well as dreams and fantasy (Iaccino, 1993; McCarthy, 1996; Oxford, 1996; Oxford, Ehrman, & Lavine, 1991; Springer & Deutsch, 1993; Torrance, 1988).

Gardner (1983) proposed a theory of multiple intelligence (MI theory) that there are eight major relatively independent dimensions of intelligence categorized as special intelligence, namely: logical-mathematical intelligence, verbal-linguistic intelligence, bodily-kenisthetic intelligence, musical intelligence, visual-spatial intelligence, interpersonal intelligence, intrapersonal intelligence and natural intelligence.

IQ tests still persist for certain purposes especially on academics tasks (Warner, et al; 1987). The first two forms of intelligences which are logical-mathematical and verbal-linguistic are characteristics of left brain thinking and are typically the abilities that contribute to strong performance in traditional school environments and produce high scores on most IQ measures or tests of achievements.

Anchored on the theories mentioned above, the researcher conducted this study in order to discover new knowledge on brain hemisphericity and mathematics achievement. Despite the numerous research undertaken related to brain hemisphericity, studies on correlation of brain hemisphericity and math achievement is still wanting.

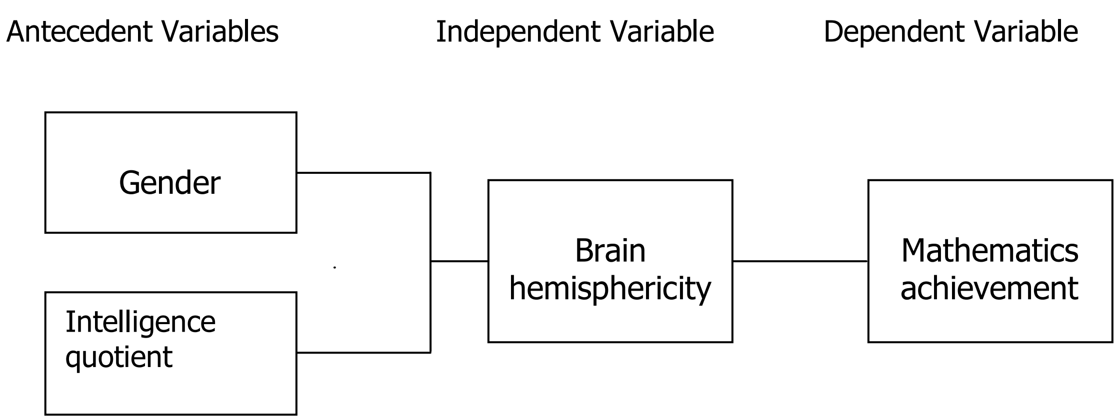

Figure 1. The paradigm of the study.

Statement of the Problem and the Hypotheses

This study aimed to determine the brain hemisphericity and mathematics achievement of the first year high school students of Colegio de San Jose (CSJ) during the school year 2010-2011.

Specifically, this study purposely sought to answer the following questions:

1. What is the dominant brain hemisphericity of the students taken as an entire group and classified according to:

a. gender, and

b. intelligence quotient?

2. What is the mathematics achievement of the students taken as an entire group and classified according to:

a. gender,

b. intelligence quotient, and

c. brain hemisphericity?

3. Is there a significant difference in the dominant brain hemisphericity of the students when classified according to:

a. gender, and

b. intelligence quotient?

4. Is there a significant difference in the mathematics achievement of the students when classified according to brain hemisphericity?

5. How do the students in each group of brain dominance solve mathematical problems?

In view of the preceding problems, the following hypotheses were tested:

1. There is no significant difference in the dominant brain hemisphericity of the students when classified according to:

a. gender, and

b. intelligence quotient.

2. There is no significant difference in the mathematics achievement of students when classified according to brain hemisphericity.

Significance of the Study

The findings of this study may give insights to students, parents, teachers, school administrators, and other researchers.

Students . The result of the study can help the students become aware of their math performance so that they can take concrete steps to improve their mathematics skills. Knowledge of their own brain dominance will lead them to discover and be aware of their own interest, strength, weakness and utilize this discovery to become more effective individuals.

Parents. The parents' awareness of their children's school performance and cognitive styles will enable them, as parents, to assist their children improve their mathematical performance by using their dominant brain and developing the less dominant to further enhance performance.

Teachers. Results of this study can help the teachers identify the students' interest and brain hemisphericity so that they can choose better teaching approaches that will best enhance students' learning especially in mathematics.

Administrators . The findings of the study may guide administrators in creating programs that match with the students' abilities. The administration can provide on-going formation for teachers especially on left-brain, right brain or bilateral individuals in order for them to achieve excellently.

Other researchers . The results of this study may motivate other researchers to conduct studies on brain hemisphericty with other variables.

Definition of Terms

For better understanding of the study, the following terms are defined conceptually and operationally:

Gender--used as synonymous for sex, referring to the physical polarity of anatomy which is commonly used to differentiate male from female (Webster's Dictionary, 1994).

In this study, *gender* referred to the male and female respondents.

Intelligence quotient--the mental age divided by chronological age, usually expressed as a multiple of 100 (Webster's Dictionary 1989).

In this study, *intelligence quotient* referred to the IQ results (categorized as high, average, or low) of the respondents obtained from the school's guidance center.

Brain hemisphericity--one of the two principal parts of the brain, each roughly hemispherical: the left or right cerebral hemispheres (http://www.wordiq 2010).

In this study, *brain hemisphericity* referred to the brain dominance of the respondents using the Hemisphere Dominance Questionnaire classified as left brain, right brain or whole brain dominance.

Mathematics Achievement --referred to the accomplishments or proficiency of performance in mathematical skills (Good, 1973; in Mijares, 2004).

In this study, *mathematics achievement* referred to the respondent's scores (described as high, average, or low) from the teacher-made Mathematics Achievement Test.

Delimitation of the Study

This descriptive research focused on the brain hemisphericity and mathematics achievement of high school students. Moreover qualitative research was considered to enrich the study. The antecedent variables were gender and intelligence quotient, while the independent variable was brain hemisphericity. The dependent variable was mathematics achievement.

The participants of the study were the first year high school students of Colegio de San Jose (CSJ) during the school year 2010-2011. CSJ, located at E. Lopez Street, Jaro, Iloilo City, Philippines is a private-sectarian school owned and managed by the Little Company of the Daughters of Charity – Philippine Province, a member of the Iloilo Integrated Administration of St. Louise de Marillac Educational System of the Daughters of Charity. This involved 168 students randomly selected from a total population of 288. The Slovin's formula of 5% margin of error was employed. The selection in choosing the participants used stratified random sampling to maintain that all the seven sections were proportionately represented.

The list of students was taken from the registrar's office and the Intelligence Quotient (IQ) or the Otis-Lennon School Ability Test (OLSAT) result was obtained from the school's guidance services center.

To gather data on brain hemisphericity, a Hemisphere Dominance Questionnaire adopted from Torrance (1980) was administered to the participants. Mathematics Achievement was based from the result of the Teacher-Made Achievement Test. In order to establish the validity and reliability of the instruments, these were validated by three experts in psychology and mathematics and pilot tested among the first year high school students of Colegio del Sagrado Corazon de Jesus.

Mean, frequency count and standard deviation were employed for descriptive analyses; and Chi-square and ANOVA wereemployed for the inferential analyses. The .05 level of significance was adopted as the criterion for rejecting or accepting the null hypothesis. To process the gathered data, the Statistical Package for the Social Sciences (SPSS) was utilized.

Chapter 2

Review of Related Literature

This chapter presents a review of literature and studies both local and foreign that have bearings on the present investigation. These include the following topics: (1) The Nature of Mathematics, (2) Mathematics Achievement; (3) Brain Hemisphericity, (4) Intelligence Quotient, and (5) The Summary.

Part One, The Nature of Mathematics, introduces the origin, evolution, and importance of mathematics.

Part Two, Mathematics Achievement, explains the articles and studies on achievement in the area of mathematics.

Part Three, Brain Hemisphericity, discusses theories and researches on brain dominance.

Part Four, Intelligence Quotient, expounds I.Q. and link to Multiple Intelligences.

Part Five, The Summary, summarizes the four preceding topics.

The Nature of Mathematics

Like every other aspect of human invention, mathematics has its origin, and like every technology, its origin is based upon the needs of mankind. The particular needs are those arising from the wants of society. The more complex the society, the more complex the needs. The primitive tribe has little mathematical needs beyond counting. The complex society's intent on building great temples, mustering skills in conquering armies, or managing large capital assets has logistical problems that demand mathematics to solve.

Long before Pythagoras considered proving the famous theorem named after him, others tackled the just-as-complex operation of counting. For some, the concept of two times two equals four is advanced beyond comprehension, and for others counting past three is very complex. That counting began more than 50,000 years ago and many people even today and even in complex societies who have trouble counting suggest that its creation was not as simple as people may believe.

Mathematics is the science of numbers and their operations, interrelations, combinations, generalizations, and abstractions and of space configurations and their structure, measurement, transformation and generalizations (Webster, 1997).

Mathematics is variously considered a language, an art, a science, a tool, and a game. It is a language agreed upon set of symbols or sounds. Mathematics may be considered the language used to express size and order. Equations and statement of inequality are mathematical sentences. Mathematical elements such as constants and variables are analogous to parts of speech. Actually, notions of artistic beauty and harmony exist in the patterns, relationships and symmetries of arithmetic and geometry. Developing new mathematical theories, concepts and system is aesthetically satisfying. This makes the study of mathematics a rewarding experience in much the same sense as the study of history, literature or music.

Mathematicians are divided into two schools of thoughts. There are those who believe that mathematics exists in nature, just a certain laws of physics exist in nature.On the other hand, there are also those who propose that mathematics is more like a work of art, a painting that does not exist until the artist creates it (Bell, 1982). There are still those who believe like the German Mathematicians Leopoldo Leronecher, that "God made the integers, all the rest is the work of man."

The Greek mathematicians Pythagoras, who lived in the sixth century B.C., also believed that not only mathematics but also everything else could be deducted from numbers since all traditional mathematics can be derived from natural mathematics.

Mathematics is the science of logical reasoning, in which valid conclusions are arrived at from a set of axioms. It involves a search for truth. It is rigorous and precise. Although some theories discovered centuries ago are still valid, mathematics continues to change and develop.

Mathematics is the tool that contains the skills for problem solving, organizing, specifying and interpreting, and performing calculations that are necessary in subjects such as science, business, and industry. The development of modern computers and electronic calculators has enabled mathematicians to solve problems that previously were extremely difficult or impossible to solve.

Some areas of mathematics were developed specifically to solve certain types of problems. One goal of mathematics is to solve problem in a systematic way so that similar problems can be solved easily in the same way. With mathematics, one can create a set of consistent rules and regulations (axioms) and proceed by logical reasoning to invent and play a mathematical game. Those who consider mathematics as a game enjoy the challenge of developing new mathematics and solving problems.

Mathematics can be divided into three major areas: higher arithmetic, algebra and geometry. Higher arithmetic is the study of structures, relation and operations in the set of integers. It is considered as the only area of mathematics whose issues form unbroken sequence of study from earliest man to today's mathematics.

Algebra involves the operation of arithmetic. Unknown numbers are represented by symbols called variables. Equation and equalities involving variables are solved for the "unknown." System of inequalities is issued to solve practical problems. The solution of linear equations leads to the study of linear algebra, in which elements are matrices and vectors.

Abstract algebra is the study of system that satisfies certain sets of axioms. Some of these structures are fields, rings, groups and domains. The elements used in abstract algebra may be numbers, vectors or even geometric transformations.

Geometry deals with the set of points in a plane or in space. The study of plane, curves, polygons and line is called plane geometry. The study of curve and three-dimensional space such as spheres, cones and cylinder and polyhedral is called solid geometry. In about 300 B.C., established sets of axioms are obeyed. Non-Euclidian geometry has been developed by denying the validity of the famous fifth postulate which states that "given a line and point not on the line, one and only one coplanar line can be drawn through the point parallel to the given line.

Mathematics Achievement

Mathematics begins with basics in addition, subtraction, multiplication and division. In order to succeed and advance in mathematics, one needs to start with basics and continue to build his prior knowledge. Mathematics is among the most ancient of subjects of instruction and has held a high place in all educational programs. More importantly, it has retained its performance because of its continued and ever increasing service to other fields.

However, Gervero (1998) explained that mathematics, to the majority of students, seems to elicit negative attitudes compared to other subjects. Students react negatively to mathematics. This reality is evidently shown in the students' poor performance in the subject.

Billones (2000) noted that one of the major problems in student's achievement in mathematics is the ability to perform task involving higher-level thinking skills which are developed through the flexibility of independent learning behaviors. Students who are bound by rigid dependence on rules and authority often lack skills needed to respond to new mathematics situations or to the irregularities of the real world's problem. Certainly, the problem must not be left to chance. Measures must be made to identify those who have the aptitude and requisite skills demanded by the desired course so that appropriate intervention schemes can be employed in order to prepare students' adequacy for their chosen field. One of these schemes should be identification of the predictors of mathematics competencies (Arroyo, 1989).

There has been considerable discussion of gender differences in mathematics achievement. Generally, the studies of gender differences in mathematics achievements report that boys scored higher than girls, especially in problem solving which involves higher order thinking skills (Fenema & Sherman, 1978; in Amor, 1999).

The study of Fenema and Carpenter (1981) revealed that males exceeded females in performance or understanding and application at age 17, while females exceeded males in multi-step problems at all ages. But in geometry and measurement exercises, the males consistently got higher scores than the females in all cognitive skills.

Mercado (1987) found out that the academic achievement of male students were poor in higher mathematics, especially those that involve mathematical reasoning and spatial relationship, whereas the achievement of the female students was better as they progress to higher levels. However, the study of Helms and Turner (1986) showed that males seem to perform better than females in tests of mathematical reasoning and visual spatial problems. Still, females tend to excel in tasks involving verbal abilities.

Schiamberge (1988) confirmed the differences in cognitive abilities between the sexes but suggested that part of the lack of scientific ability in girls maybe due to cultural values, societal expectations, and sex role stereotypes.

Polya (1962) described mathematical problem as finding a way around a difficulty, around an obstacle, and finding a solution to a problem that is unknown.

According to Kantowski (1997) an individual is faced with a problem when he encounters a question he cannot answer or a situation he is unable to resolve using the knowledge immediately available to him. He must then think of a way to use the information at his disposal to arrive at the goal, the solution of the problem. For task to be considered mathematical problem, they must be developmentally appropriate for students (Lesh & Zawojewski, 2007). A challenging problem solving task for a first grader may only be a routine word problem for a fifth grader.

According to Newman (1983), difficulty in problem solving may occur at one of the following phases namely: reading comprehension, strategy know-how, transformation, process skill and solution.

Polya (1985) in his book "How to Solve It" suggested the following four-phase plan for solving problems: (1) understanding the problem, (2) devising a plan to solve the problem, (3) carrying out the plan to solve the problem, and (4) looking back at the completed solution to review and discuss it.

Schoenfeld (1985) stated that students are not actually weak in solving problems, but they lack the skill to marshal strategies that help solve particular problems.

In her study, Saleh (2004) discovered that students who can successfully solve a problem possess good reading skills, are able to compare and contrast, have the ability to identify important aspects of the problem, are able to estimate and to create analogies and are flexible in attempting to use various strategies.

Mahmud (2003) found that the main source of secondary school students' difficulties in solving mathematical problem is their inability to understand the problem. She found out that almost 98% of students admitted to having difficulties in comprehending what a question required. Students did not pay much attention to the strategies involved in answering the question, and did not read the terms used in the problem very closely. This shows that students face difficulties in solving word problems.

Brain Hemisphericity

The right brain / left brain Theory has it that the brain has two hemispheres (commonly called the right brain and the left brain) which think in different ways. The right brain is visual and processes information by looking first at the whole picture then the details. The left brain is verbal and processes information by looking at the pieces then putting them together to get the whole. The right brain is more intuitive; the left is analytical and sequential (Evans, 2010).

According to Bradshaw (1996) brain hemisphericity is the tendency of an individual to process information through the left hemisphere or the right hemisphere or in combination. Oxford (1996) cited that research has demonstrated that the left hemisphere operates in a linear, sequential manner with logical, analytical, prepositional thought. On the other, the right hemisphere operates in a non-linear, simultaneously fashion and deals with non-verbal information as well as dreams and fantasy. The left hemisphere appears to be specialized for language, whereas the right hemisphere is specialized for Visio-spatial and oppositional thought. Ohrman and Laviner (1991) maintained that the left hemispheric dominants are highly analytical, verbal, linear and logical learner, whereas right hemispheric dominants are highly global, visual, emotional and intuitive learners. Whole brain dominants are those who process information through both hemispheres equally and exhibits characteristics of both hemispheres.

Ohrman and Laviner (1991) cited that research has demonstrated that students are capable of mastery of new skills if they are taught through instructional method that complements their hemispheric preference. Several studies have found that students taught through methods that matched their hemispheric style achieved statistically significant higher test score that they were taught through other teaching methods. Studies have suggested that brain hemisphericity is associated with different occupations and academic majors. Bernan, Bruno and Kolb (1984) believed that people choose major/fields based on the congruence between their learning styles and the norms of those major/fields. People chose their academic majors based on the capability between norms of these disciplinary fields and the individual hemisphere dominance. Academic subjects such as arts, the humanities and architecture are believed by several researchers to require a more global, synthetic, and spatial orientation which make them more suitable for right brain dominant students, whereas other subjects such as science, engineering and language emphasized logic and verbal analysis, which make them better fit for left-brain dominants students.

Lavach (1991) examined the hemisphericity of the students with different majors. He reported that humanities students showed preference for the right-hemispheric dominance. Natural science students demonstrated a left-hemispheric mode, while social science majors showed preference for left hemispheric dominance. The left-brain has no trouble processing symbols. Many academic pursuits deal with symbols such as letter, words and mathematical notations. The left-brain person tends to be comfortable with linguistic and mathematical endeavors. Left brained students will probably just memorize vocabulary words or math formulas.

The right brain, on the other hand, want things to be concrete. The left-brain persons want to see, feel or touch the real object. Right brain students may have trouble learning to read using phonics. They prefer to see words in context, to see how the formula works.

Saleh (2001) investigated the correlation between students' choice of academic majors and their brain hemisphericity. The participants in this research were 429 graduate and undergraduate students in a large university in the southern part of the United States. The data were analyzed using analysis of variance to determine the influence of brain hemisphericity on students' choice of academic majors. The results lent support to earlier research in their findings of a strong correlation between academic majors and brain dominance. The ANOVA model showed a significant effect of brain hemisphericity on students' choice of academic majors. Arts/literature students tended to be right brained while business/commerce students were left brained. Students majoring in education, nursing, communication, and law were right brained, while students majoring in business/commerce, engineering, and science were left brained. The study also demonstrated an evidence of a general shift in students' brain hemisphericity from earlier research, where more students were identified as whole brained.

The participants were asked to complete a demographic survey as well as McCarthy's Hemispheric Mode Indicator (HMI) instrument to determine their individual brain hemisphericity. The Hemispheric Mode Indicator was developed to measure the preference in the individual's approach to learning with a bias for right, left, or whole brain-mode processing techniques (McCarthy, 1987).

The Cronbach's alpha of the instrument is 0.90. The test-retest reliability (Pearson product moment correlation coefficient) is 0.904 (Lieberman, 1986). The HMI items were correlated, to check current validity, with the items of Torrance's measure of hemispheric dominance (Your Style of Learning and Thinking, SOLAT-C). The Spearman rank correlation coefficient is 0.819. The Pearson product-moment correlation is 0.659.

Oliver (2009) examined the associations between problem solving strategies and brain hemisphericity. A total of 98 ninth grade students were randomly selected from a high school in South East Texas. Results showed that as hypothesized, students who tested high for left brain dominance tended to prefer a written, logical explanation strategy to solve certain complexity levels of the mathematics problem. Also, as hypothesized, students who tested high in right brain dominance, tended to prefer drawing diagrams to solve certain complexity levels of the mathematics problems. He further reported that the relationships identified in this study showed that the general characteristics associated with each hemisphere of the brain, also apply to mathematical problem.

There are many differences between the two hemispheres of the brain. The persons nature largely depends on which part of his brain dominates the nervous system (Naik, 2009).The right brain is intuitive, meaning it is led by feelings, while the left brain is analytical, meaning it is led by logical approach towards problems. Right brain tends to make lateral connection from the derived information, whereas left brain tends to make logical deductions from the derived information. The right brain is visual, stressing on music and pattern, while the left brain is verbal, stressing on words, numbers and symbols. Right brained people struggle with mathematical formulas and words to express themselves, while left brained people are very good at memorizing mathematical formulas and also express them pretty well. In people with right brain domination, organizational skills are very poor, on the other hand people with left brain domination are highly organized. People with right brain don't give attention to minute details, but people with left brain tend to focus on each and every minute detail and step taken. When given a task of assembling a particular thing, right brain people will start working promptly without reading the instructions, while left brained people will carefully go through the instructions and then start working. When people with right brain communicate, they tend to make many gestures with their hands, contrary to which left brain people hardly use gestures when communicating. Right brain is designed to listen to 'how' something is being said, while left brain is designed to listen to 'what' is being said. Although right brained people don't rationalize things they do have the tendency to question the rules, on the other hand left brained people never question rules, instead they readily accept them.

People with dominant right brain have difficulty in prioritizing things which makes them execute things in hurry at the last moment, whereas people with dominant left brain are well versed with planning the future which makes them be prepared well in advance (Nick, 2005).

In general, the left and right hemispheres of the brain process information in different ways. A person tend to process information using the dominant side. However, the learning and thinking process is enhanced when both sides of the brain participate in a balance manner. This means strengthening the less dominant hemisphere of the brain (Restalk, 2002).

Intelligence Quotient

The term IQ comes from German Intelligenz–Quotient. This was coined by the German psychologist William Stern in 1912 as a proposed method of scoring early modern children's intelligence tests such us those developed by Alfred Binet and Theodore Simon in the early 19th century (Makintosh, 1998).

IQ is a number used to express the apparent relative intelligence of a person that is the ratio multiplied by 100 of mental age as reported on a standardized test to the chronological age. IQ is a cognitive ability, such as the ability to learn or understand or to deal with new situations; the skilled use of reason; the ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria (as tests); mental acuteness; logic and analytical skills. Binet's test was explicitly designed to measure school abilities. IQ scores do correlate moderately well with grades in school. It is related to the "academic tasks" (auditory and linguistic measures, memory task, academic achievement levels) and much less related to task where even precise handwork "motor function" are required (Warner et al; 1987).

IQ scores are used in many contexts: as predictors of educational achievement or special needs, by social scientists who study the distribution of IQ scores in populations and the relationships between IQ score and other variables, and as predictors of job performance and income (Johnson et al; 2009).

French psychologist Alfred Binet, together with Victor Henri and Theodore Simon, after about 15 years of development, published the Binet-Simon test for the practical use of determining educational placement. The score on the Binet-Simon scale would reveal the child's mental age. For example, a 6 year-old child who passed all the tasks usually passed by 6 year-olds—but nothing beyond—would have a mental age that exactly matched his chronological age, 6.0. Binet was forthright about the limitations of his scale. He stressed the remarkable diversity of intelligence and the subsequent need to study it using qualitative, as opposed to quantitative measures. Binet also stressed that intellectual development progressed at variable rates and could be influenced by the environment; therefore, intelligence was not based solely on genetics. It was malleable rather than fixed, and could only be found in children with comparable background. American psychologist Henry H. Goddard published a translation of it in 1910. The eugenics movement in the USA seized on it as a means to give them credibility in diagnosing mental retardation. American psychologist Lewis Terman at Stanford University revised the Binet-Simon scale which resulted in the Stanford-Binet Intelligence Scales (1916). It became the most popular test in the United States for decades. Finally, when Binet did become aware of the "foreign ideas being grafted on his instrument" he condemned those who with 'brutal pessimism' and 'deplorable verdicts' were promoting the concept of intelligence as a single, unitary construct (Richardson, 2003).

Carroll (1993) after a comprehensive re-analysis of earlier data proposed the Three Stratum Theory, which is a hierarchical model with three levels. At the bottom is the first stratum which consists of narrow abilities. The second stratum consists of broad abilities. Carroll identified eight second-stratum abilities and accepted Spearman's concept of general intelligence, for the most part, as a representation of the uppermost third stratum.

The American Psychological Association's report "Intelligence: Knowns and Unknowns" states that wherever it has been studied, children with high scores on tests of intelligence tend to learn more of what is taught in school than their lower-scoring peers. The correlation between IQ scores and grades is about .50. This means that the explained variance is 25%. Achieving good grades depends on many factors other than IQ, such as persistence, interest in school, and willingness to study (Neisser, 1995).

Psychometricians generally regard IQ tests as having high statistical reliability. A high reliability implies that while test-takers can have varying scores on differing occasions when taking the same test and can vary in scores on different IQ tests taken at the same age, the scores generally agree. A test-taker's score on any one IQ test is surrounded by an error band that shows, to a specified degree of confidence, what the test-taker's true score is likely to be. For modern tests, the standard error of measurement is about 3 points, or in other words, the odds are about 2 out of 3 that a persons true IQ is in range from 3 points above to 3 points below the test IQ. Another description is that there is a 95% chance that the true IQ is in range from 4-5 points above to 4-5 points below the test IQ, depending on the test in question. Clinical psychologists generally regard them as having sufficient statistical validity for many clinical purposes (Kaufman, 2009).

Men and women have statistically significant differences in average scores on tests of particular abilities. Studies also illustrate consistently greater variance in the performance of men compared to that of women (Lynn and Irwing, 2004).

IQ tests are weighted on these sex differences so there is no bias on average in favor of one sex; however, the consistent difference in variance is not removed. Because the tests are defined so there is no average difference,it is difficult to put any meaning on a statement that one sex has a higher intelligence than the other. However some people have made claims like this even using unbiased IQ tests. For instance, there are claims that men tend to outperform women on average by three to four IQ points based on tests of medical students where the greater variance of men's IQ can be expected to contribute to the result, or where a correction is made for different maturation ages (Stumpf & Jackson, 1994).

The average IQ scores for many populations have been rising at an average rate of three points per decade since the early 20th century, a phenomenon called the Flynn effect. It is disputed whether these changes in scores reflect real changes in intellectual abilities (Flynn, 1987).

IQ can change to some degree over the course of childhood. However, in one longitudinal study, the mean IQ scores of tests at ages 17 and 18 were correlated at r=.86 with the mean scores of tests at ages 5, 6 and 7 and at r=.96 with the mean scores of tests at ages 11, 12 and 13. IQ scores for children are relative to children of a similar age. That is, a child of a certain age does not do as well on the tests as an older child or an adult with the same IQ. But relative to persons of a similar age, or other adults in the case of adults, they do equally well if the IQ scores are the same (Kaufman, 2009).

The theory of multiple intelligences was proposed by Howard Gardner in 1983 as a model of intelligence that differentiates intelligence into various specific (primarily sensory) modalities, rather than seeing it as dominated by a single general ability.

Gardner (1983) argues that there are wide variety of cognitive abilities which are only very weakly correlated with one another, despite the close correlations between aspects of intelligence generally measured by traditional intelligence (IQ) tests or psychometrics. For example, the theory predicts that a child who learns to multiply easily is not necessarily generally more intelligent than a child who has more difficulty on this task. The child who takes more time to master simple multiplication may best learn to multiply through a different approach, may excel in a field outside of mathematics, or may even be looking at and understand the multiplication process at a fundamentally deeper level. Such a fundamentally deeper understanding can result in what looks like slowness and can hide a mathematical intelligence potentially higher than that of a child who quickly memorizes the multiplication table despite a less detailed understanding of the process of multiplication.

The theory's eight currently accepted intelligences are: spatial, linguistic, logical-mathematical, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic (Gardner & Seana, 2006).

Spatial deals with spatial judgment and the ability to visualize with the mind's eye. Careers which suit those with this type of intelligence include artists, designers and architects. A spatial person is also good with puzzles. Linguistics has to do with words, spoken or written. People with high verbal-linguistic intelligence display a facility with words and languages. They are typically good at reading, writing, telling stories and memorizing words along with dates. Logical-mathematical has to do with logic, abstractions, reasoning and numbers. While it is often assumed that those with this intelligence naturally excel in mathematics, chess, computer programming and other logical or numerical activities, a more accurate definition places less emphasis on traditional mathematical ability and more on reasoning capabilities, recognizing abstract patterns, scientific thinking and investigation and the ability to perform complex calculations. It correlates strongly with traditional concepts of "intelligence" or IQ. The core elements of the bodily-kinesthetic intelligence are control of one's bodily motions and the capacity to handle objects skillfully. Gardner elaborates to say that this intelligence also includes a sense of timing, a clear sense of the goal of a physical action, along with the ability to train responses so they become like reflexes. Musical has to do with sensitivity to sounds, rhythms, tones, and music. People with a high musical intelligence normally have good pitch and may even have absolute pitch, and are able to sing, play musical instruments, and compose music. Since there is a strong auditory component to this intelligence, those who are strongest in it may learn best via lecture.

Interpersonal has to do with interaction with others. In theory, people who have a high interpersonal intelligence tend to be extroverts, characterized by their sensitivity to others' moods, feelings, temperaments and motivations, and their ability to cooperate in order to work as part of a group. They communicate effectively and empathize easily with others, and may be either leaders or followers. They typically learn best by working with others and often enjoy discussion and debate. Intrapersonal has to do with introspective and self-reflective capacities. People with intrapersonal intelligence are intuitive and typically introverted. They are skillful at deciphering their own feelings and motivations. This refers to having a deep understanding of the self; what his/her strengths/weaknesses are, what makes him/her unique, he/she can predict his/her own reactions/ emotions.

Naturalistic has to do with nurturing and relating information to one's natural surroundings. Careers which suit those with this intelligence include naturalists, farmers and gardeners. Some proponents of multiple intelligence theory proposed spiritual or religious intelligence as a possible additional type. Gardner did not want to commit to a spiritual intelligence, but suggested that an "existential" intelligence may be a useful construct. The hypothesis of an existential intelligence has been further explored by educational researchers.

The theory of multiple intelligence break the psychometricians' century-long stranglehold in the subject of Intelligence Quotient or IQ (Gardner, 1999). However, IQ tests still persist for certain purposes especially on academics tasks (Warner, et al, 1987). The first two forms of intelligences which are logical-mathematical and verbal-linguistic are characteristics of left brain thinking and are typically the abilities that contribute to strong performance in traditional school environments and produce high scores on most IQ measures or tests of achievements.

Traditionally, schools have emphasized the development of logical intelligence and linguistic intelligence (mainly reading and writing). IQ tests (given to about 1,000,000 students each year) focus mostly on logical and linguistic intelligence as well. While many students function well in this environment, there are those who do not. Gardner's (1998) theory argues that students will be better served by a broader vision of education, wherein teachers use different methodologies, exercises and activities to reach all students, not just those who excel at linguistic and logical intelligence.

Defenders of MI theory argue that the traditional definition of intelligence is too narrow, and thus broader definition more accurately reflects the differing ways in which humans think and learn. They would state that the traditional interpretation of intelligence collapses under the weight of its own logic and definition, noting that intelligence is usually defined as the cognitive or mental capacity of an individual, which by logical necessity would include all forms of mental qualities, not simply the ones most transparent to standardized I.Q. tests (Sternberg, 1991).

Summary

This chapter covers the general overview of all topics included in this study.

Mathematics is the science of logical reasoning, in which valid conclusions are arrived at from a set of axioms. It involves a search for truth. It is rigorous and precise. Although some theories discovered centuries ago are still valid, mathematics continues to change and develop.

Gervero (1998) explained that mathematics, to the majority of students, seems to elicit negative attitudes compared to other subjects. Students react negatively to mathematics. This reality is evidently shown in the students' poor performance in the subject.

Billones (2000) noted that one of the major problems in student's achievement in mathematics is the ability to perform task involving higher-level thinking skills which are developed through the flexibility of independent learning behaviors. Students who are bound by rigid dependence on rules and authority often lacks skills needed to respond to new mathematics situations or to the irregularities of the real world's problem.

There has been considerable discussion of gender differences in mathematics achievement. Generally, the studies of gender differences in mathematics achievements report that boys scored higher than girls, especially in problem solving which involves higher order thinking skills (Fenema & Sherman, 1978; in Amor, 1999).

However, a study conducted by Peterson and Carpenter (1985) concluded that there are no sex difference in mathematics learning from kindergarten to third grade. Differences in the performance of the sexes began to emerge in the fourth grade and in the ninth grade, but they were not significant. Girls were slightly superior to boys in computation while boys were found to be slightly superior to girls in mathematical reasoning.

Mercado (1987) found out that the academic achievement of male students were poor in higher mathematics, especially those that involve mathematical reasoning and spatial relationship, whereas the achievement of the female students was better as they progress to higher levels. However, the study of Helms and Turner (1986) showed that males seem to perform better than females in tests of mathematical reasoning and visual spatial problems. Still, females tend to excel in tasks involving verbal abilities.

Schiamberge (1988) confirmed the differences in cognitive abilities between the sexes but suggested that part of the lack of scientific ability in girls maybe due to cultural values, societal expectations, and sex role stereotypes.

The right brain / left brain theory has it that the brain has two hemispheres (commonly called the right brain and the left brain) which think in different ways. The right brain is visual and processes information by looking first at the whole picture then the details. The left brain is verbal and processes information by looking at the pieces then putting them together to get the whole. The right brain is more intuitive; the left is analytical and sequential (Evans, 2010).

Oliver (2009) examined the associations between problem solving strategies and brain hemisphericity. A total of 98 ninth grade students were randomly selected from a High School in South East Texas. Results showed that as hypothesized, students who tested high for left brain dominance tended to prefer a written, logical explanation strategy to solve certain complexity levels of the mathematics problem.

Also, as hypothesized students who tested high in right brain dominance, tended to prefer drawing diagrams to solve certain complexity levels of the mathematics problems. He further reported that the relationships identified in this study showed that the general characteristics associated with each hemisphere of the brain, also apply to mathematical problem.

The term IQ comes from German Intelligenz–Quotient. This was coined by the German psychologist William Stern in 1912 as a proposed method of scoring early modern children's intelligence tests such us those developed by Alfred Binet and Theodore Simon in the early 19^{th} century.

The theory of multiple intelligences was proposed by Howard Gardner in 1983 as a model of intelligence that differentiates intelligence into various specific (primarily sensory) modalities, rather than seeing it as dominated by a single general ability.

The theory's eight currently accepted intelligences are: spatial, linguistic, logical-mathematical, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic.

Intelligence quotient tests still persist for certain purposes especially on academics tasks (Warner, et al; 1987). The first two forms of Multiple Intelligences (Gardner, 1983) which are logical-mathematical and verbal-linguistic are characteristics of left brain thinking and are typically the abilities that contribute to strong performance in traditional school environments and produce high scores on most IQ measures or tests of achievements.

Men and women have statistically significant differences in average scores on tests of particular abilities. Studies also illustrate consistently greater variance in the performance of men compared to that of women.

Gender and IQ and how these two variables affect the brain hemisphericity and mathematics achievements have led the researcher to conduct the study on brain hemisphericity and mathematics achievement of high school students.

Chapter 3

Research Design and Methodology

Chapter 3 consists of three parts: (1) Purpose of the Study and Research Design, (2) Method, and (3) Statistical Data Analysis Procedure.

Part One, Purpose of the Study and Research Design, presents the design adopted in this investigation.

Part Two, Method, describes the participants and the method of choosing them, the instruments used in gathering data and the procedure of the study.

Part Three, Statistical Data Analysis Procedure, presents the statistics used to test the hypotheses.

Purpose of the Study and Research Design

The descriptive method of research was used in this study. According to Gay (1992), descriptive research involves collecting data in order to test hypothesis or to answer questions concerning the current status of the respondents. It determines and reports the way things are. Moreover, qualitative method was also employed to answer the question on how students in each group of brain dominance solve mathematical problems.

The antecedent variables were gender and intelligence quotient. Independent variable is brain hemisphericity while the dependent variable was mathematics achievement.

Method

Respondents

The study was conducted among the first year high school students of Colegio de San Jose, during the school year 2010-2011. This study involved 168 students randomly selected from a total of 288. In the selection, the researcher employed the Slovin's formula of finding the sample: $n= N/(1 +Ne^2)$ with 5% margin of error. The sample represented around 58% of the total population. Stratified random sampling was employed so that the seven sections were equally represented.

The distribution of the respondents is shown in Table 1.

Table 1

The Distribution of the Respondents

Category	f	%
Entire group	168	100
Gender		
Male	88	52.4
Female	80	47.6
Intelligence quotient		
Low	128	76.2
Average	40	23.8
High	0	0.00

Instrumentation

There were three instruments used in this study: Hemisphere Dominance Questionnaire (HDQ), Mathematics Achievement Test (MAT), and Interview Schedule (IS).

In order to establish the validity of the instruments HDQ and MAT, these were validated by experts of the field, three psychologists for HDQ and another three mathematicians for MAT and IS. Corrections were integrated to make the final instruments. The instruments were then pilot tested among the first year high school students of Colegio del Sagrado Corazon de Jesus who were of the same characteristics as the identified respondents.

For reliability of the instruments, MAT had a Cronbach's Alpha of .733 while HDQ had a Cronbach's of .826. The alpha coefficient was within the acceptable range (Mcmillan, 1992). For predictive validity, Mathematics Achievement Test and IQ results from the pilot tested group were correlated with Pearson r of .745.

To obtain the data on students' brain dominance , HDQ was used. This was adopted from Torrance (1980). It consists of 50-items. Descriptions for Column A represent left brain dominance, the Column B for right brain dominance, and Column C for whole brain dominance. Students answered by putting an X in the appropriate column, A, B, C beside the description that was most like them. Only one X mark was needed in each item, either that mark is in column A, B or C.

To determine the dominant brain hemisphericity the following steps were done:

1. The score was computed by counting the number of X's for column A, column B and column C.

2. Column A score was subtracted from column B score.

3. The column C score was taken.

If the C score was 15 or higher, the "column B score – column A score" in step 2 was divided by 3, and the answer was rounded to the nearest whole number. The answer was the score which can either be a negative or positive number.

If the C score was from 9 to 14, the "column B score – column A score" in step 2 was divided by 2, and the answer was rounded off to the nearest whole number. The answer was the score which either can be a negative or positive number.

If the C score was less than 9, "column B score – column A score" in step 2 was not divided at all. The result of step 2 was the answer.

A negative score meant left brain dominance. A positive score meant right brain dominance while a score of zero meant whole brain dominance.

Mathematics achievement was based from the result of the researcher-made MAT. This consisted of two parts: Part One, a 40-item multiple choice and Part Two, a 6-item open-ended questions. Items covered topics on measurement, plane figures, solid figures, integers, algebraic expressions, and linear equations in one variable. These topics were lessons in the first and second quarters of first year curriculum and within the DepEd minimum requirements. A scoring rubrics adopted from Belarga (2007) was used in the scoring of problem solving.

Intelligence Quotient (IQ) or the Otis-Lennon School Ability Test (OLSAT) was described as low, average, or high if the results were 95 and below, 96 - 127, and 128 and above respectively.

For the qualitative part, the researcher prepared an IS consisting of five questions which were answered by the selected 20 students, 10 of them were identified as left brain dominance and another 10 were identified right brain dominance. The questions centered on how do students in each group of brain dominance solve problems. The IS is shown in Appendix F.

Procedure

The list of students with gender identification was taken from the registrar's office. IQ results were obtained from the school's guidance service center. Prior to obtaining these data, the researcher wrote a letter to the registrar and the guidance counselor of the school. Information was treated with confidentiality and used only for the purpose of this study.

The researcher also wrote to the principal of CSJ asking permission to administer the instrument of the study. Upon approval, the schedule of testing was set and the participants were given one hour and a half to answer the two questionnaires. Few days after, 20 participants identified as left and right brain dominant were subjected for interview.

Results of the gathered data were tallied, tabulated, computer-processed, analyzed and interpreted.

Statistical Data Analysis Procedure

The data gathered for the study were subjected to computer-processed statistics which included the following statistical tools:

Mean. To obtain mean scores to describe the respondents' mathematics achievement, the mean was employed.

Frequency count. Frequency count was used to determine the number of participants belonging to a category.

Standard deviation. To find out the homogeneity and heterogeneity of respondents' mathematics achievement, the standard deviation was utilized.

Chi-square. Chi-square was used to determine the significant difference in dominant brain hemisphericity of students when classified according to gender and IQ.

Analysis of variance (ANOVA). To obtain the significant difference in the mathematics achievement of students when classified according to brain hemisphericity, ANOVA was employed.

Content and documentary analyses were used in the qualitative data by looking into the respondents' solution to problem solving. This was supplemented by their answers during the interview.

The Statistical Package for Social Science (SPSS) program was utilized in processing the gathered data. The .05 level of significance was adopted as the criterion for rejecting or accepting the null hypotheses.

Chapter 4

Results

Chapter 4 is divided into three parts: (1) Descriptive Data Analysis, (2) Inferential Data Analysis, and (3) Content and Documentary Analyses.

Part One, Descriptive Data Analysis, presents the descriptive data and their respective analyses and interpretations.

Part Two, Inferential Data Analysis, presents the inferential data and their respective analysis and interpretations.

Part Three, Qualitative Data Analysis, presents the ways on how students solve math problems and their responses in the interview.

Descriptive Data Analysis

To determine the brain hemisphericity of the students, the frequency count and percentages were obtained.

Table 2 presents the brain hemisphericity of the students as an entire group. Of the 168 students, 84 or 50% were left brain dominant; 57 or 33.9% were right brain dominant; and 27 or 16.1% were whole brain learners. This simply showed that the dominant brain hemisphericity of the first year students at Colegio de San Jose was the left brain.

Ali (2007) analysis revealed that 71% of the sample of his study were left-brain dominant (n=30) whereas 24% (n=10) were right-brain dominant and the remainders (n=2) were whole-brain learners in his study. Marquelenza (2004) also reported similar findings left brain dominance among his subjects.where the dominant brain hemisphericity of her subjects was left brain too.

Table 2

Brain Hemisphericity of Students as an Entire Group

Category	f	%
Brain hemisphericity		
Left brain	84	50.0
Right brain	57	33.9
Whole brain	27	16.1
Total	168	100

The results in Table 3 showed the brain hemisphericity of the respondents when they were classified according to gender. Out of 88 male respondents, 41 or 46.6% were left brain dominant; 35 or 38.9% were right brain dominant; and 12 or 13.6% were whole brain learners. Among the female participants, 43 or 53.8% were left brain dominant; 22 or 27.5 were right brain dominant; and 15 or 18.8% were whole brain learners. This showed that both the male and female students were left brain dominant.

Table 3

Brain Hemisphericity of Students Grouped as to Gender

Category	Gender			
	Male		Female	
	f	%	f	%
Brain hemisphericity				
Left brain	41	46.6	43	53.8
Right brain	35	39.8	22	27.5
Whole brain	12	13.6	15	18.8
Total	88	100	80	100

The results in Table 4 showed the brain hemisphericity of the respondents when they were classified according to intelligence quotient. Out of the 128 students belonging to the low classification, 64 or 50% were left brain dominant; 46 or 35.9% were right brain dominant; and 18 or 14.1% were whole brain learners. Among the

40 students belonging to the average classification, 20 or 50% were left brain dominant; 11 or 27.5 were right brain dominant; and 9 or 22.5% were whole brain learners. This showed that the dominant brain hemisphericity of the students in either low or average classifications was the left brain. There was no student belonging to the high IQ classification.

IQ can change to some degree over the course of childhood. However, in one longitudinal study, the mean IQ scores of tests at ages 17 and 18 were correlated at r=.86 with the mean scores of tests at ages 5, 6 and 7 and at r=.96 with the mean scores of tests at ages 11, 12 and 13. IQ scores for children are relative to children of a similar age. That is, a child of a certain age does not do as well on the tests as an older child or an adult with the same IQ. But relative to persons of a similar age, or other adults in the case of adults, they do equally well if the IQ scores are the same (Carroll, 1999).

Table 4

Brain Hemisphericity of Students Grouped as to Intelligence Quotient

Category	Intelligence Quotient			
	Low		Average	
	f	%	f	%
Brain Hemisphericity				
Left brain	64	50.0	20	50.0
Right brain	46	35.9	11	27.5
Whole brain	18	14.1	9	22.5
Total	128	100	40	100

The results in Table 5 showed the mathematics achievement of students when taken as an entire group and when classified according to gender, intelligence quotient, and brain hemisphericity. As an entire group, the students had "average" mathematics achievements *(M = 24.92, SD = 6.33).*

When the participants were grouped according to gender, both males *(M = 23.88, SD = 6.72)* and females *(M = 26.06, SD = 5.69)* had "average" mathematics achievement.

As to the intelligence quotient, students classified in the low IQ group low *(M = 22.86, SD = 5.03)* and students classified in the average IQ group *(M = 31.50, SD = 5.56)* had "average" mathematics achievement.

As to the brain hemisphericity, left brain dominant *(M = 25.63, SD = 6.51)*; right brain dominant *(M = 23.84, SD = 6.80)*; and whole brain learners *(M = 24.96, SD = 6.32)* all had "average" mathematics achievement.

The dispersion around the mean and SD are more or less the same for the different categories involved.

Table 5

Mathematics Achievement of Students Taken as an Entire Group and Classified as to Gender, Intelligence Quotient and Brain Hemisphericity

Category	*n*	*M*	Description	*SD*
Entire group	168	24.92	average	6.33
Gender				
Male	88	23.88	average	6.72
Female	80	26.06	average	5.69
Intelligence quotient				
Low	128	22.86	average	5.03
Average	40	31.50	average	5.56
Brain hemisphericity				
Left brain	84	25.63	average	6.51
Right brain	57	23.84	average	6.80
Whole brain	27	24.96	average	6.32

Scale	*Description*
43.01 and above	High
22.01 – 43	Average
22 and below	Low

Inferential Data Analysis

The Chi-square and ANOVA were used to determine the significant differences among variables. Significance was set at .05 alpha.

Differences in the Brain Hemisphericity of students

As shown in Table 6 no significant difference existed in the brain hemisphericity of students when classified according to gender $X^2 = 0.226$, $p > .05$, and as to intelligence quotient, $X^2 = 0.370$, $p > .05$. Thus, the null hypothesis stating that there is no significant difference in the dominant brain hemisphericity of students when classified according to gender and intelligence quotient was accepted.

This result supports the study conducted by Peterson and Carpenter (1985) wherein they concluded that there are no sex difference in mathematics learning from kindergarten to third grade. Differences in the performance of the sexes began to emerge in the fourth grade and in the ninth grade, but they were not significant. Girls were slightly superior than boys in computation while boys were found to be slightly superior than girls in mathematical reasoning. Ali (2007) also found out that there was no significant association between brain hemisphericity with gender.

Table 6

Chi-Square Results for Differences in the Brain Hemisphericity of Students Classified According to Gender and Intelligence Quotient

Category	X^2	*df*	Sig.
Gender	2.972	2	0.226
Intelligence Quotient	1.989	2	0.370

Differences in the Mathematics Achievement of Students

As shown in Table 7 no significant difference existed in the mathematics achievement of students when classified according to brain hemisphericity $F(2, 165) = 1.363$, $p > .05$. Therefore, the null hypothesis stating that there is no significant difference in the mathematics achievement of students when classified according to brain hemisphericity was accepted. It can be deduced that both left and right brain students perform equally in math.

Marquelenza (2004) similarly found that academic achievement in mathematics among college freshmen was not significantly different when they were categorized according to brain dominance. The absence of significant difference in the mathematics achievement of participants could be attributed to the fact that the learners learn individually based on their strengths and weaknesses (Sulit, 2005).

Table 7

ANOVA Results for Differences in the Mathematics Achievement of Students Classified According to Brain Hemisphericity

Sources of Variation	Sum of squares	*df*	Mean squares	*F*	Sig.
Between groups	108.732	2	54.366	1.363	0.259
Within groups	6580.101	165	39.879		
Total	6688.833	167			

Qualitative Data Analysis

To answer the research question on how do students in each group of brain dominance solve a mathematical problem, content and documentary analyses were applied. Students answers to problem solving were scored using the rubrics.

To gather data, 20 randomly selected students 10 coming from the left-brain group and 10 from the right brain group were interviewed.

When solving problems, the left-brain dominant students used written explanation and equation (Appendix H), while the right-brain dominant students drew diagrams or pictures in their solution (shown in Appendix H). This supports the study of Oliver (2009) stating that those who tested high for left brain dominance tended to prefer a written, logical explanation strategy to certain complexity levels of problem solving and those who tested high in right brain dominance tended to prefer drawing diagrams to solve certain complexity levels of the mathematics problems.

Whether students are left or right brain dominant, their scores revealed that only a few could completely give solution to the problem. Majority got a rating of 2 or 1 or even 0 based from the rubrics scale. This shows that students find it difficult to solve word problems. Mahmud (2003) found that the main source of secondary school students' difficulties in solving mathematical problem is their inability to understand the problem. She found out that almost 98% of students admitted to having difficulties in comprehending what a question required. Students did not pay much attention to the strategies involved in answering the question, and did not read the terms used in the problem very closely.

When asked if they understood the problem, all 20 participants replied "yes." When made to identify the strategy they used to come up with the correct answer, The left-brain dominant group replied the following:

1) *"I analyze and understand the problem very well. I solved all the problems step by step and I did the trial and error method;"*

2) *" I was able to know about the PEMDAS, using of equation and shortcuts of solving problems. Solving about meter, liter, and gram;"*

3) *" I use to solve the problem, read the question properly and I understand it;"*

4) *"First is, I try to understand and find out ways in order to get the correct answer. But before answering any problem I tried to recall everything that I had learned before. Everything that came up was actually introduced to me when I was in Grade 6 and my previous school. Every formula, terms and similar problems were actually familiar to me. That's why I actually know how to solve a particular problem;"*

(5) *"I first answered the easier problems and skip the difficult ones and then after answering the easier ones, I go back to the difficult problems."*

The answers of the left-brain group somehow show some logical ways in solving problems.

Here are some answers from the right-brain dominant group:

1) *"The strategy that I use was the strategy given to us by our math teacher on how to solve a certain problem and a problem which was given to us as a sentence;"*

2) *"Using diagram or illustration;"*

3) *"I find what is given, then I try to figure out the correct formula. Once I finally understood it all then I try my best to answer it correctly. However, this strategy will prove invalid if I don't understand the question given;"*

4) *"The strategy is to understand the problem correctly;"*

5) *"I used my basic learning about mathematics in order to get the correct answer."*

The answers of the right-brain group somehow show their preference of using illustration.

Students from both brain groups indicated some of the strategies in problem solving. These have similarities to Polya's (1985) suggestions using the following four-phase plan for solving problems: (1) understanding the problem, (2) devising a plan to solve the problem, (3) carrying out the plan to solve the problem, and (4) looking back at the completed solution to review and discuss it.

The students were also asked if the strategy they used were introduced to them before. Most of them answered "yes". When querried, what other ways do they think can solve the problem, and introduce the process, the left-brain dominant group answered the following:

1) "*I give the formula first, then I tried to solve it step by step. 1. Analyze the problem, 2. Identify what problem it is, 3. Give the formula, and 4. Solve it step by step*;"

2) "*I just put for example ½ =.5. Multiplication, addition, subtraction and division is important. I memorized the multiplication table in order for me to solve easily;"*

3*)" Use the four fundamental operations, use formula in solving area, volume and surface area;"*

4) "*The other ways that I think I can solve the problem is by showing the process so that you can make sure that your answer is correct;"*

(5) "*In finding the circumference, we must use the formula C = 2r x Π. In finding the area, we use the formula s x s*."

Something common among the answers of the left-brain dominant group are the rules that they would follow which really are characteristics of the left brain dominant.

Here again are the responses from the right-brain dominant group.

1) "*The other ways to solve a certain problem is to simply understand the question then think of a strategy or process which suited to the problem*;"

2) "*Using diagrams, using drawings;"*

3*)" I could just answer them systematically until I finished them all. I would do my best to answer them all;"*

4) "*By thinking or being conscious and very understanding. You have to read and remember stored knowledge. But if you have trouble with that then try to think about it and just answer what you know, because sooner or later as you answer you will remember how to get an answer to the other problems or try to familiarize;"*

5) "*I first read the problem thoroughly and thought about the processes or equations to be used. Afterwards, I first answered the easier ones than the hard ones.*"

Answers show that they are creative since they would prefer using drawings or diagrams. They have the tendency to pick up items randomly whichever is easier for them. These really are manifestations of the right brain dominant.

Responses of the students showed that they tried their best in answering the problems. Schoenfeld (1985) stated that students are not actually weak in solving problems, but lack the skill to marshal strategies that help solve particular problems. In her study, Salleh (2004) discovered that students who can successfully solve a problem possess good reading skills, are able to compare and contrast, have the ability to identify important aspects of the problem, are able to estimate and to create analogies and are flexible in attempting to use various strategies.

The students were asked what difficulties did they encounter in solving the problem. The left-brain dominant group, have these responses:

1) "*That I have to solve or find out if what is exactly the answer*;"

2) "*There are so many difficulties I encountered like knowing the areas and many more*;"

3) "*Analyzing the problem. I find it hard to understand*;"

4) "*The difficulties I had encountered is when I'm solving about the radius of a cylinder because I can't remember the lessons we had*;"

5) "*The difficulties I did encounter in solving the problem is by solving algebraic expression*."

The right-brain group's answers are:

1) "*I encountered a lot of difficult problems, most of them involve the linear function/equation*;"

2) "*The difficulties that I've encountered in solving the problem is some of the problems are hard for me to understand and due to lack of knowledge in any topic*;"

3) "*The difficulties I have encountered is when I forget something or get mental blocked about the processes to be used in the problems*;"

4) "*Most of my problems were from geometry since most of it was to familiarize and recall geometric processes*;"

5) "*The difficulties that I encountered were forgetfulness and not understanding the problem. I forgot part of the process and for some of the questions*."

As expressed in their answers, students encountered various difficulties in analyzing problems whether they may be left or right brain dominant. According to Kantowski (1997), an individual is faced with a problem when he encounters a question he cannot answer or a situation he is unable to resolve using the knowledge immediately available to him. He must then think of a way to use the information at his disposal to arrive at the goal, the solution of the problem.

Chapter 5

Summary, Conclusions, Implications, and Recommendations

Chapter 5 contains four parts: (1) Summary of the Problem, Method, and Findings, (2) Conclusions, (3) Implications, and (4) Recommendations.

Part One, Summary of the Problem, Method, and Findings, reflects the vital points of the study and the results.

Part Two, Conclusions, gives the inferences drawn from the results of the study.

Part Three, Implications, clarifies the relationships between the findings of the present investigation and the theories presented in relation to the present study.

Part Four, Recommendations, offers suggestions in terms of the findings, implications, and conclusions.

Summary of the Problem, Method, and Findings

This study aimed to determine the brain hemisphericity and mathematics achievement of the first year high school students of Colegio de San Jose (CSJ) during the school year 2010-2011.

Specifically, this study purposely sought to answer the following questions:

1. What is the dominant brain hemisphericity of the students taken as an entire group and classified according to:

a. gender, and

b. intelligence quotient?

2. What is the mathematics achievement of the students taken as an entire group and classified according to:

a. gender,

b. intelligence quotient, and

c. brain hemisphericity?

3. Is there a significant difference in the dominant brain hemisphericity of the students when classified according to:

a. gender, and

b. intelligence quotient?

4. Is there a significant difference in the mathematics achievement of the students when classified according to brain hemisphericity?

5. How do the students in each group of brain dominance solve mathematical problems?

In view of the preceding problems, the following hypotheses were tested:

1. There is no significant difference in the dominant brain hemisphericity of the students when classified according to:

a. gender, and

b. intelligence quotient.

2. There is no significant difference in the mathematics achievement of students when classified according to brain hemisphericity.

Data for the study were obtained using the three sets of instruments, Hemisphere Dominance Questionnaire (HDQ) adopted from Torrance, Mathematics Achievement Test (MAT), and Interview Schedule (IS).

The descriptive statistics employed were frequency count, mean and standard deviation while the inferential statistics were chi-square and ANOVA, all set at .05 alpha. The Statistical Package for Social Sciences (SPSS) software was employed in the analysis of data gathered.

The findings of the present study revealed that:

1. The dominant brain hemisphericity of the students as an entire group and when classified according to gender and intelligence quotient was the left brain.

2. The mathematics achievement of students as an entire group and when classified according to gender, intelligence quotient, and brain hemisphericity was *average.*

3. No significant difference existed in their dominant brain hemisphericity when they were classified according to gender and intelligence quotient.

4. No significant difference existed in their mathematics achievement when they were classified according to brain hemisphericity.

5. In solving mathematical problems, the left- brain students tend to write an equation and make logical explanation while the right-brain students tend to make diagrams and illustrations.

Conclusions

Based on the findings of the study, the following conclusions were drawn:

It appears that the dominant brain hemisphericity of the participants was the left brain and their mathematics achievement was *average*.

The absence of significant difference in the dominant brain hemisphericity of students when grouped according to gender and intelligence quotient could be attributed to the fact that the learners learn individually based on their strengths and weaknesses. It is apparent that no gender is superior than the other and that the average or low IQ is not respective of one's brain hemisphericity.

The not significant difference in their mathematics achievement when they were classified according to brain hemisphericity may be attributed to the fact that learners are not necessarily strong left or strong right brain dominant since both group seem to perform equally. The teaching approach towards the subject matter somehow caters to the three types of brain hemisphericity. Exposure of the students to the classroom environment reflect the level of achievement they attain.

Solution of the students in the problem solving part made use of particular strategies which somehow reflect the characteristics of left or right brain dominant students.

Implications

The findings of the present study have led to certain implications for theory and practice in relation to the brain hemisphericity and mathematics achievement of high school students.

For theory. The right brain / left brain theory stresses that the brain has two hemispheres (commonly called the right brain and the left brain) which think in different ways (Evans, 2010).

The left-brain dominant person tends to be comfortable with linguistic and mathematical endeavors. The right-brain, on the other hand, wants things to be concrete. Ali (2007) found out that most respondents were left brain dominated. In addition, results revealed that left brain dominant individuals tend to be sensing and sequential learners.

Ohrman and Laviner (1991) cited that students are capable of mastery of new skills if they are taught through instructional method that complements their hemispheric preference. Several studies have found that students taught through methods that matched their hemispheric style achieved statistically significant higher test score than they were taught through other teaching methods. This may be the reason why students belonging to low IQ classification have *average* mathematics achievement.

In general, the left and right hemispheres of the brain process information in different ways. One tends to process information using the dominant side. However, the learning process is enhanced when all of the senses are used. This includes using the less dominant hemisphere. According to Kichura (2005) the right and left hemispheres also work together and need each other for the brain to operate effectively.

For practice. The findings of this study will challenge all mathematics teachers to determine the brain hemisphericity and mathematics achievement of their students. Student's brain dominance somehow influences one's learning style which leads to better achievement. It is when students' learning styles are matched with appropriate approaches in teaching that their motivation, performance, and achievement will increase and be enhanced (Brown, 1994). This information could be used to help develop more whole brained mathematical problem solvers, by teaching strategies that are associated with both hemispheres (Oliver, 2009).

William and Murr (1987) mentioned that teachers' increased awareness of learning styles and brain hemisphericity and their efforts to include a variety of teaching methods and learning activities and students' increased exposure to video games and computer activities are believed to promote imagination and spatial skills.

Schoenfeld (1985) stated that students are not actually weak in solving problems, but lack the skill to marshal strategies that help solve particular problems. In her study, Saleh (2004) discovered that students who can successfully solve a problem possess good reading skills, are able to compare and contrast, have the ability to identify important aspects of the problem, are able to estimate and to create analogies and are flexible in attempting to use various strategies.

Newman (1983) noted that difficulty in problem solving may occur at one of the following phases namely: reading comprehension, strategy know-how, transformation, process skill and solution.

Educators, therefore, must always seek solutions to the perennial problem solving difficulties of the students. They should employ varied strategies to address the varying needs of the learners.

Recommendations

Based on the findings and conclusions of this study, the following recommendations are advanced:

Students should study their math lessons diligently, memorize the formulas with understanding where these came from, and learn and apply the different strategies in solving problems. Awareness of their brain dominance will lead them to discover effective study habits in order to have high achievement in math subjects.

Teachers should be aware of student's dominant brain. In this way the application of teaching techniques can be adjusted in order to fit dominant brain and the needs of the students in the classroom so that effective learning could be effected. Attendance to seminars is highly recommended to give more ideas to teachers to develop effective teaching techniques that match with the teaching style preference of dominant brain.

Parents should be informed of their children's brain dominance and mathematics performance so that they can assist in the studies of their children.

The school administration should include in their faculty development program seminars of teachers on brain hemisphericity and on improving their mathematical skills using such concept. This information can help administrators in secondary schools and advisors in higher education to place students in programs that are compatible with their interests and abilities.

Other researchers may use the result of this study in conducting studies related to brain hemisphericity involving wider scope and more variables. An experimental study may be conducted grouping students according to brain hemisphericity.

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APPENDIXES

APPENDIX A

The Jurors

The Jurors

DR. MA. LUZPERCY M. ABOLUCION
Dean, Higher Education Department
Colegio de San Jose

MISS MARY JUNE MAYORDOMO
Faculty, Mathematics Area
High School Department
Colegio de San Jose

MR. NESTOR GICARAYA
Math Area Coordinator
Assumption Iloilo

DR. CATHERINE O. ROCES
Guidance Counselor
West Visayas State University

PROF. METHUSELAH V. ADELANTAR
Guidance Counselor
West Visayas State University

APPENDIX B

Letter to the Jurors

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

February 12, 2011

DR. MA. LUZPERCY M. ABOLUCION
Dean, Higher Education Department
Colegio de San Jose

Dear Dr. Abolucion:

Peace!

The undersigned is undergoing thesis writing entitled " Brain Hemisphericity and Mathematics Achievement of High School Students" in partial fulfillment of the requirements for the degree, Master of Arts in Education (Mathematics).

In this connection, I am respectfully requesting your favor to validate my instrument on Mathematics Achievement Test.

I would be very grateful for your consideration regarding this matter.

More power and God bless.

Very truly yours,

SANNY F. FERNANDEZ
Candidate, M.A. Ed. Mathematics

Noted by:

ALONA M. BELARGA, Ph. D.
Thesis Adviser

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

February 12, 2011

DR. CATHERINE O. ROCES
Guidance Counselor
West Visayas State University

Dear Dr. Roces:

Peace!

The undersigned is undergoing thesis writing entitled " Brain Hemisphericity and Mathematics Achievement of High School Students" in partial fulfillment of the requirements for the degree, Master of Arts in Education (Mathematics).

In this connection, I am respectfully requesting your favor to validate my instrument on Brain Hemisphericity.

I would be very grateful for your consideration regarding this matter.

More power and God bless.

Very truly yours,

SANNY F. FERNANDEZ
Candidate, M.A. Ed. Mathematics

Noted by:

ALONA M. BELARGA, Ph. D.
Thesis Adviser

APPENDIX C

Letter to the Principals

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

February 23, 2011

PROF. JOJIE ERMEL LAUREA
Principal
Colegio del Sagrado Corazon de Jesus

Dear Prof. Laurea:

Peace!

The undersigned is undergoing thesis writing entitled " Brain Hemisphericity and Mathematics Achievement of High School Students" in partial fulfillment of the requirements for the degree, Master of Arts in Education (Mathematics).

In this connection, I am respectfully requesting your favor to allow me to pilot test my instruments on Mathematics Achievement and Brain Hemisphericity among the first year high school students in your school the soonest time possible preferably not later than March 4, 2011. One section will take Mathematics Achievement Test and another section will take Brain Hemisphericity test. The tests will last for more or less one hour only.

I would be very grateful for your consideration.

More power and God bless.

Very truly yours,

SANNY F. FERNANDEZ
Candidate, M.A. Ed. Mathematics

Noted by:

ALONA M. BELARGA, Ph. D.
Thesis Adviser

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

March 9, 2011

MISS JERLYN DADIOS
Principal
Colegio de San Jose

Dear Ms. Dadios:

Peace!

The undersigned is undergoing thesis writing entitled " Brain Hemisphericity and Mathematics Achievement of High School Students" in partial fulfillment of the requirements for the degree, Master of Arts in Education (Mathematics).

In this connection, I am respectfully requesting your favor to allow me to administer my instruments on Mathematics Achievement and Brain Hemisphericity to the randomly selected 168 out of 288 first year high school students the soonest time possible, preferably not later than March 2011.

Mathematics Achievement Test (MAT) Part I, a 40-item Multiple Choice and Hemisphere Dominance Questionnaire will last for one and a half (1 ½) hour. MAT Part II, Problem Solving will be given for one hour preferably the following day.

Moreover, twenty (20) students, 10 identified as left and 10 as right brain dominant will be subjected for interview within one week after the examination.

I would be very grateful for your positive response.

Very truly yours,

SANNY F. FERNANDEZ
Candidate, M.A. Ed. Mathematics

Noted by:

ALONA M. BELARGA, Ph. D.
Thesis Adviser

APPENDIX D

Letter to the Registrar

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

March 9, 2011

MISS EMELY LARIOSA
Registrar
Colegio de San Jose

Dear Miss Lariosa:

Peace!

The undersigned is undergoing thesis writing entitled "Brain Hemisphericity and Mathematics Achievement of High School Students" in partial fulfillment of the requirements for the degree, Master of Arts in Education (Mathematics).

In this connection, I am respectfully requesting from your office the list of first year high school students this school year 2010-2011.

I would be very grateful for your positive response.

More power and God bless.

Very truly yours,

SANNY F. FERNANDEZ
Candidate, M.A. Ed. Mathematics

Noted by:

ALONA M. BELARGA, Ph. D.
Thesis Adviser

APPENDIX E

Letter to the Guidance Counselor

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

March 9, 2011

MISS JOERLYN BALANDRA
Coordinator, Guidance Services Center
Colegio de San Jose

Dear Miss Balandra:

Peace!

The undersigned is undergoing thesis writing entitled “Brain Hemisphericity and Mathematics Achievement of High School Students” in partial fulfillment of the requirements for the degree, Master of Arts in Education (Mathematic).

In this connection, I am respectfully requesting from your office the Intelligence Quotient (IQ) score or the Otis-Lennon Mental Ability Test result of the first year high school students for this year 2010-2011.

I would be very grateful for your consideration. Thank you very much.

More power and God bless.

Very truly yours,

SANNY F. FERNANDEZ
Candidate, M.A. Ed. Mathematics

Noted by:

ALONA M. BELARGA, Ph. D.
Thesis Adviser

APPENDIX F

Sample Research Instruments

WEST VISAYAS STATE UNIVERSITY
COLLEGE OF EDUCATION
GRADUATE SCHOOL
Iloilo City

Mathematics Achievement Test

Name: ____*Score:* _____________
Grade/Year Level and Section: ________________________*Equivalent:* _________
Adviser: ____*Date:* _____________

Test I MULTIPLE CHOICE

Directions: Read each item carefully. Choose the letter of the correct answer and place it on the blank before the number. See to it that you answer every item. (40 items)

_____1. What is the basic unit of length in the metric system?
a. meter b. liter c. gram d. celsius

_____2. Which of the following is equal to three meters?
a. 300 mm b. 30 dkm c. 0.3 dm d. 0.003 km

_____3. Which of the following is equal 150 decigram?
a. 1.5 kg b. 15 g c. 15, 000 cg d. 150,000 mg

_____4. How many pounds are there in 10 kilograms?
a. 2.2 lbs b. 22 lbs c. 50 lbs d. 220 lbs

_____5. Which of the following is approximately the same as one glass of water?
a. 200 ml b. 2 cl c. 0.3 hl d. 0.002 kl

_____6. Which of the following is equal to five liters?
a. 0.05 kl b. 50 dkl c. 50 dl d. 50,000 ml

_____7. Three centuries is equal to how many years?
a. 20 b. 30 c. 100 d. 300

_____8. Eight hours is equivalent to how many seconds?
a.3,600 b. 28,800 c. 80,000 d. 100,000

_____9. What is the length of a side of a square if the perimeter is 25 m?
a. 4.5 m b. 5 m c. 6.25 m d. 8 m

_____10. What is the perimeter of a regular hexagon if the side is 4.2 cm?
a. 22.5 cm b. 25.2 cm c. 30 cm d. 42 cm

Test II PROBLEM SOLVING

Directions: Analyze each item. Show your solution on the space below each number. Try your best to answer each item. (5 items)

1. Suppose you need to measure exactly one (1) cup of water. All that you have in your kitchen are two containers. The smaller container holds three (3) cups and the larger holds five (5) cups. How can you use these two containers to measure exactly one (1) cup of water?

2. A square room five (5) meters to a side will be laid with square tiles, each side of which is 10 centimeters. How many tiles will be used in all?

3. Find the surface area of a cube whose side is 20 centimeter long.

4. Find the volume of a cylinder five (5) meters tall with a radius of three (3) meters. Use $\pi = 3.14$.

5. The Yellow Team was 6 points ahead of the Blue Team at the end of the third quarter. With 2 minutes remaining in the final quarter, the Yellow' lead was cut down to 5 points. Before the bell rang, however, De Villa of the Blue team made a 3-point score. Who won the game?

6. Red took the elevator at the fourth floor. He went up 3 floors and then went down 5 floors. What floor is he in now?

Hemisphere Dominance Questionnaire

Name: ____________________ *Score:* ____________________
Grade/Year Level and Section: ____________________ *Equivalent:* ____________________
Adviser: ____________________ *Date:* ____________________

Directions: Answer by putting an X in the appropriate column, A, B, or C for the description that is MOST like you. Mark only one X for each item.

#	**Description**	**A**	**A**	**B**	**B**	**C**	**C**
1	I remember best…	names		faces		both names & faces	
2	I prefer to have things explained to me…	with words		by showing them to me		both ways	
3	I prefer classes…	with one assignment at a time		where I work on many things at once		both ways	
4	I prefer…	multiple choice tests		essay tests		both kinds of tests	
5	I am…	not good at body language, I prefer to listen to what people say		good at body language		sometimes good, but other times not good	
6	I am…	not good at thinking of funny things to say and do		good at thinking of funny things to say and do		sometimes good	
7	I prefer classes…	where I listen to "experts"		in which I move around and try things		where I listen and also try things	
8	I decide what I think about things…	by looking at the facts		based on my experience		both ways	
9	I tend to solve problems…	with a serious, business-like approach		with a playful approach		with both approaches	
10	I like…	to use proper materials to get jobs done		to use whatever is available to get jobs done		a little of both	
11	I like my classes or work to be…	planned so I know exactly what to do		open with opportunities for changes as I go along		both planned and open to changes	

Interview Schedule

How do students in each group of brain dominance solve mathematical problem?

1. Did you understand the problem?
2. What strategy did you use to come up with the correct answer?
3. Was the strategy used introduced to you before?
4. In what other ways do you think can you solve the problem? Would you mind to introduce the process?
5. What difficulties did you encounter in solving the problem?

TABLE OF SPECIFICATION

Topics/Contents	Number of Items: Multiple Choice	Number of Items: Problem Solving
A. Measurement		1
1. length	2	
2. Weight	2	
3. Capacity	2	
4. Time	2	
B. Plane Figures		1
1. Perimeter/Circumference	4	
2. Area	4	
C. Solid Figures		
1.Surface Area	4	
2. Volumes	4	
D. Integers		2
1. Absolute Value	1	
2. Operation on Integers	4	
E. Algebraic Expression		
1. Evaluating Algebraic Expression	1	
2. Operation on Algebraic Expression	4	
F. Linear Equation in One Variable		
1. Properties of Equality	2	
2. Word Problem	4	
Total Number of Items	**40**	**6**

APPENDIX G

Scoring Rubrics

Criteria for Rating Students' Solutions/Explanations in the Problem Solving Test

Description	Points	Criteria
No attempt at a solution/ explanation	0	The student made no attempt to solve the problem.
Fails to begin effectively	1	Some work (processes/explanations) was present, but the student showed no understanding of the problem.
Begins problem with some understanding	2	The student used an inappropriate strategy, proceeded to get an incorrect answer, but the work showed some understanding of the problem; OR The student started toward a solution/explanation that reflected some understanding of the problem, but that start could not lead to a solution; OR The student used appropriate strategy, but failed to implement the strategy correctly.
Fairly complete solution/ explanation	3	(The student used an appropriate strategy but the process/explanation is fairly complete; OR The student implemented appropriate strategies, but a copying or computation error prevented him from getting the correct answer.) AND Solid supporting arguments for the solution/explanation are presented, but some aspects are not clearly explained. Some terms are not properly used.
Complete solution/ explanation	4	The student give a complete solution/explanations; AND The explanation of the process/techniques used in solving the problem is clear and accurate; AND The solution/explanation shows full understanding of mathematical concepts and processes involved.

APPENDIX H

Sample Solutions to Problem Solving

Left Brain Students

3. Find the surface area of a cube whose side is 20 centimeter long.

SA of cube = $s^2 6$
$s = 20\text{cm}$

$SA_{\square} = (20^2)6$
$= 400(6)$
$= 2400\ \text{cm}^2$

∴ the surface area of cube is 2400cm^2

5. The Yellow Team was 6 points ahead of the Blue Team at the end of the third quarter. With 2 minutes remaining in the final quarter, the Yellow' lead was cut down to 5 points. Before the bell rang, however, De Villa of the Blue team made a 3-point score. Who won the game?

Yellow Team	3rd Quarter Blue team
6pt.	
5pt.	3pt.

∴ Yellow team won the game.

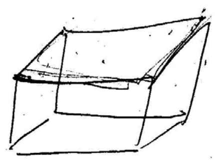
6. Red took the elevator at the fourth floor. He went up 3 floors and then went down 5 floors. What floor is he in now?

$$\begin{array}{r} 4 \\ +\ 3 \\ \hline 7 \\ -\ 5 \\ \hline 2 \end{array}$$

he is now on second floor.

Right Brain Students

3. Find the surface area of a cube whose side is 20 centimeter long.



20
20
400
x 6
2,400

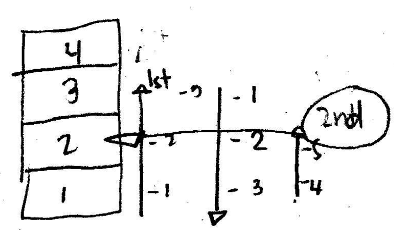
$2,400\ cm^2$

5. The Yellow Team was 6 points ahead of the Blue Team at the end of the third quarter. With 2 minutes remaining in the final quarter, the Yellow' lead was cut down to 5 points. Before the bell rang, however, De Villa of the Blue team made a 3-point score. Who won the game?

Yellow – [redacted] 6 – 1 = 5
Blue – 0 + 3 = 3

Yellow won the game with 2 points ahead from the blue team

6. Red took the elevator at the fourth floor. He went up 3 floors and then went down 5 floors. What floor is he in now?



2nd Floor

APPENDIX I

Reliability Coefficients of the Research Instruments

Reliability (Mathematics Achievement Test)

Warnings

The space saver method is used. That is, the covariance matrix is not calculated or used in the analysis.

Case Processing Summary

		N	%
Cases	Valid	39	100.0
	Excluded[a]	0	.0
	Total	39	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.733	46

```
R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

                                                       N of
Statistics for        Mean    Variance     Std Dev   Variables
      SCALE        35.8462     38.0810      6.1710          46

_
```

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Alpha if Item Deleted
VAR00001	34.8974	37.6208	.1497	.7314
VAR00002	35.4103	36.2483	.2612	.7260
VAR00003	35.6923	37.0081	.2112	.7288
VAR00004	35.5385	35.5182	.4206	.7190
VAR00005	35.0256	36.9204	.2137	.7286
VAR00006	34.8462	38.0810	.0000	.7335
VAR00007	35.0513	37.2078	.1414	.7314
VAR00008	34.8462	38.0810	.0000	.7335
VAR00009	35.2564	37.7746	.0095	.7379
VAR00010	35.0769	35.7045	.4302	.7195
VAR00011	34.9487	37.4184	.1511	.7310
VAR00012	35.5385	34.7287	.5686	.7121
VAR00013	35.6154	38.0850	-.0354	.7385
VAR00014	35.2564	35.8273	.3362	.7224
VAR00015	35.6667	36.6491	.2721	.7265
VAR00016	35.6667	38.3333	-.0838	.7395
VAR00017	35.6154	38.0850	-.0354	.7385
VAR00018	35.7179	37.5236	.1067	.7324
VAR00019	35.3846	38.5587	-.1168	.7439
VAR00020	35.6154	35.9798	.3748	.7218
VAR00021	35.3333	35.9123	.3151	.7234
VAR00022	35.1795	35.6248	.3908	.7201
VAR00023	35.6410	37.0256	.1784	.7299
VAR00024	35.4615	36.6235	.2036	.7288
VAR00025	35.3333	35.7018	.3508	.7216
VAR00026	35.2308	34.4980	.5769	.7107
VAR00027	35.6154	36.8219	.2079	.7287
VAR00028	35.1795	35.3090	.4482	.7174
VAR00029	35.1282	35.3779	.4601	.7175
VAR00030	35.7436	37.2483	.1968	.7297
VAR00031	35.0513	37.8920	.0043	.7366
VAR00032	35.6154	36.9271	.1873	.7295
VAR00033	35.3590	36.6572	.1904	.7295
VAR00034	35.3846	37.1377	.1118	.7332
VAR00035	35.1026	37.8313	.0099	.7369
VAR00036	35.6154	35.8745	.3959	.7209
VAR00037	35.4359	36.5155	.2187	.7281
VAR00038	35.1026	36.7787	.2062	.7287

VAR00039	35.2821	35.8920	.3217	.7231
VAR00040	35.2821	36.1552	.2770	.7253
VAR00041	34.2564	35.7220	.0832	.7502

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R E L I A B I L I T Y   A N A L Y S I S - S C A L E (A L P H A)

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Alpha if Item Deleted
VAR00042	33.3590	37.0256	.1103	.7338
VAR00043	33.4872	36.0985	.1602	.7333
VAR00044	33.5897	34.6694	.4367	.7155
VAR00045	32.6410	36.0783	.1308	.7371
VAR00046	32.0000	37.5789	.0822	.7333

Reliability Coefficients

N of Cases = 39.0   N of Items = 46

Alpha = .7332

Reliability (Hemisphere Dominance Questionnaire)

Warnings

The space saver method is used. That is, the covariance matrix is not calculated or used in the analysis.

Case Processing Summary

		N	%
Cases	Valid	36	100.0
	Excluded[a]	0	.0
	Total	36	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.826	50

```
R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

                                                          N of
Statistics for       Mean    Variance     Std Dev   Variables
      SCALE      101.6944    165.5325     12.8659          50

_
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R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Alpha if Item Deleted
VAR00001	99.2222	160.8063	.2401	.8240
VAR00002	99.0556	167.1397	-.1355	.8303
VAR00003	99.7778	162.5206	.1149	.8271
VAR00004	99.7222	156.9492	.3142	.8221
VAR00005	99.1389	157.4373	.3667	.8209
VAR00006	99.1111	159.0159	.3723	.8214
VAR00007	99.1389	166.6373	-.0853	.8316
VAR00008	99.3611	157.4373	.3753	.8207
VAR00009	100.1389	162.0659	.1283	.8269
VAR00010	100.0000	161.3143	.1519	.8265
VAR00011	100.0000	156.0000	.3939	.8199
VAR00012	99.4167	160.2500	.2697	.8233
VAR00013	99.5833	155.7357	.3753	.8203
VAR00014	99.3056	159.3040	.3100	.8224
VAR00015	99.6944	161.2468	.1816	.8254
VAR00016	99.3611	152.1230	.5958	.8145
VAR00017	99.8611	157.8373	.2880	.8229
VAR00018	99.6389	154.1230	.4600	.8179
VAR00019	99.6944	158.9611	.2819	.8230
VAR00020	99.6667	162.8571	.1483	.8257
VAR00021	99.8333	156.6000	.3770	.8204
VAR00022	99.6944	156.1611	.3834	.8202
VAR00023	99.7778	159.0921	.2574	.8236
VAR00024	100.0833	166.3643	-.0771	.8298
VAR00025	99.1667	159.2286	.3101	.8224
VAR00026	99.8333	155.0571	.4504	.8184
VAR00027	99.6667	160.0000	.2255	.8244
VAR00028	99.3611	164.6944	.0270	.8281
VAR00029	99.5833	158.2500	.3202	.8220
VAR00030	99.6111	151.3873	.6494	.8132
VAR00031	99.6111	157.7302	.3066	.8223
VAR00032	100.3056	168.3897	-.1956	.8324
VAR00033	100.2778	163.9778	.0682	.8274
VAR00034	99.5833	157.9071	.2936	.8227
VAR00035	99.9167	162.3643	.1097	.8275
VAR00036	100.0000	163.3714	.1003	.8268
VAR00037	99.9444	163.3683	.1167	.8263
VAR00038	99.5278	157.1706	.4507	.8194

VAR00039	99.4444	155.7968	.3940	.8199
VAR00040	99.1667	157.6857	.4517	.8197
VAR00041	99.3611	158.7516	.2780	.8231

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Alpha if Item Deleted
VAR00042	99.5556	159.1683	.2696	.8233
VAR00043	99.9167	154.8786	.4076	.8193
VAR00044	100.2500	159.7929	.2800	.8231
VAR00045	99.4444	161.2254	.2029	.8248
VAR00046	99.8333	160.6571	.2374	.8240
VAR00047	99.7500	158.9929	.2551	.8237
VAR00048	99.5556	155.1111	.4920	.8178
VAR00049	99.9444	158.5683	.3723	.8212
VAR00050	100.1389	165.5516	-.0230	.8285

Reliability Coefficients

N of Cases = 36.0   N of Items = 50

Alpha = .8263

APPENDIX J

Predictive Validity

PREDICTIVE VALIDITY

Correlations

Correlations

		IQ	MAT
IQ	Pearson Correlation	1	.745**
	Sig. (2-tailed)	.	.000
	N	39	39
MAT	Pearson Correlation	.745**	1
	Sig. (2-tailed)	.000	.
	N	39	39

**. Correlation is significant at the 0.01 level

APPENDIX K

SPSS Outputs

Frequencies

Statistics

		GENDER	brain hemisph ericity	intelligennce quotient
N	Valid	168	168	168
	Missing	0	0	0

Frequency Table

GENDER

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	88	52.4	52.4	52.4
	female	80	47.6	47.6	100.0
	Total	168	100.0	100.0	

brain hemisphericity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	left brain	84	50.0	50.0	50.0
	right brain	57	33.9	33.9	83.9
	whole brain	27	16.1	16.1	100.0
	Total	168	100.0	100.0	

intelligennce quotient

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low	128	76.2	76.2	76.2
	average	40	23.8	23.8	100.0
	Total	168	100.0	100.0	

Crosstabs

brain hemisphericity * GENDER Crosstabulation

			GENDER		
			male	female	Total
brain hemisphericity	left brain	Count	41	43	84
		% within GENDER	46.6%	53.8%	50.0%
	right brain	Count	35	22	57
		% within GENDER	39.8%	27.5%	33.9%
	whole brain	Count	12	15	27
		% within GENDER	13.6%	18.8%	16.1%
Total		Count	88	80	168
		% within GENDER	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.972[a]	2	.226
Likelihood Ratio	2.992	2	.224
Linear-by-Linear Association	.032	1	.858
N of Valid Cases	168		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.86.

Crosstabs

brain hemisphericity * intelligennce quotient Crosstabulation

			intelligennce quotient		
			low	average	Total
brain hemisphericity	left brain	Count	64	20	84
		% within intelligennce quotient	50.0%	50.0%	50.0%
	right brain	Count	46	11	57
		% within intelligennce quotient	35.9%	27.5%	33.9%
	whole brain	Count	18	9	27
		% within intelligennce quotient	14.1%	22.5%	16.1%
Total		Count	128	40	168
		% within intelligennce quotient	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.989[a]	2	.370
Likelihood Ratio	1.920	2	.383
Linear-by-Linear Association	.395	1	.530
N of Valid Cases	168		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.43.

Oneway

Descriptives

math achievement

	N	Mean	Std. Deviation	Std. Error
left brain	84	25.6310	6.51001	.71030
right brain	57	23.8421	6.80543	.90140
whole brain	27	24.9630	4.24700	.81734
Total	168	24.9167	6.32874	.48827

ANOVA

math achievement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	108.732	2	54.366	1.363	.259
Within Groups	6580.101	165	39.879		
Total	6688.833	167			

Means

math achievement * GENDER

math achievement

GENDER	Mean	N	Std. Deviation
male	23.8750	88	6.72072
female	26.0625	80	5.69109
Total	24.9167	168	6.32874

math achievement * brain hemisphericity

math achievement

brain hemisphericity	Mean	N	Std. Deviation
left brain	25.6310	84	6.51001
right brain	23.8421	57	6.80543
whole brain	24.9630	27	4.24700
Total	24.9167	168	6.32874

math achievement * intelligennce quotient

math achievement

intelligennce quotient	Mean	N	Std. Deviation
low	22.8594	128	5.02707
average	31.5000	40	5.55624
Total	24.9167	168	6.32874