Relationships Between Problem Solving Strategies and Brain Hemisphericity in High School Students

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RELATIONSHIPS BETWEEN PROBLEM SOLVING STRATEGIES AND BRAIN HEMISPHERICITY IN HIGH SCHOOL STUDENTS

HONORS THESIS

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By

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Abstract

The associations between problem solving strategies and brain hemisphericity are examined. The hypothesis is that there is a correlation between the methods used to solve a single opened-ended mathematics problem and the scores obtained in the Style of Learning and Thinking Questionnaire, which measures student's brain dominance (Torrance, 1988). A total of 98 ninth grade students were randomly selected from a High School in South East Texas to be surveyed. The students completed a demographic questionnaire, an open-ended mathematics problem and the Style of Learning and Thinking questionnaire.

Results show 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 problems. Also, as hypothesized, students who tested high in right brain dominance, tended to prefer drawing diagrams to solve certain complexity levels of the mathematics problem. However, the listing method did not correlate with left brain dominance as expected on any level of complexity of the mathematics problem. The relationships identified in this study show that the general characteristics associated with each hemisphere of the brain, also apply to mathematical problem solving. This information could be used to help develop more whole brained mathematical problem solvers, by teaching strategies that are associated with both hemispheres.

Acknowledgements

I would like to thank God for all of the blessings and opportunities I have been given.

My Parents- Thank you Mom and Dad for all of the ways you have helped me. From the time I was little you always encouraged me to give 110% in everything I started. You have both been the best examples of how to do this and you have always supported me in everything I have done. Thank you for all of the things you have taught me and for all the love and support you have provided. I love you both and I am so thankful that I was blessed with such great parents.

Dr. Sorto- Thank you so much Dr. Sorto for your patience and guidance. From the 10:00 pm phone calls to the hours of meetings in your office, you were always there giving me support. Having never met me before, you took a chance and gave me the opportunity to learn so much about Mathematics Education. I can never repay you for all the ways you have helped me. Thank you so much.

Dr. McCabe- Thank you Dr. McCabe for helping me develop an idea. I came to you lost and overwhelmed and you helped me to formulate my topic. Maybe now I can study the accuracy of the thumb test!

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Entering my senior year at Texas State University, I realized that I would soon be standing in front of a class of high school students faced with the task of teaching them one of the most difficult subjects of their education, mathematics. As I pondered this challenge, I decided to visit some of my professors for advice. I eventually ended up in the office of a professor I had never met, Dr. Terence McCabe. Dr. McCabe has taught for 20 years at Texas State University and received the 2003 Presidential Teaching Award, the Alumni Teaching Award and the Outstanding Teaching Award from the College of Science several times. Dr. McCabe has a very unique approach to teaching mathematics. He does not rely on the typical methods of using textbooks, guided practice and structured strategies. McCabe uses the strategies of discovery learning and the inquiry based teaching method. For example, in his approach to teaching general problem solving, McCabe encourages his students to answer four questions; (1) What do you know? (2) What are you trying to show? (3) Can you draw a picture? And (4) Does this remind you of anything you have already done? His methods focus more on the use of exploration problems, rather than simply following examples. My discussion with Dr. McCabe, lead to the revelation of one of his favorite problems, known as the hand shake problem. After working through this problem, I learned something very important about myself. I had always thought of myself as being very left-brained. By left-brained, I mean that I identify with all of the typical tasks in which the left hemisphere of the brain specializes. For example, I am a very logical, organized and sequential type of person. As I approached the handshake problem, I immediately started with my left brain ways of thinking, but then something strange happened. I quickly changed to a method that was more representative of right brain characteristics. Was I more whole-brained than I thought? Or did this particular problem push me to use other methods? This moment is what led to the development of my thesis project. I wanted to find out if the ways in which we approach mathematical problem solving are related to the hemisphere of the brain in which we are dominant. It was also possible that this information could help me as a teacher, and possibly the field of mathematics education. After Dr. McCabe and I discussed the possible connection between hemispheric dominance and approaches to problem solving, he introduced me to another professor by the name of Dr. Alejandra Sorto. Dr. Sorto is another professor at Texas State recognized for her teaching. She has received the Graduate Student Excellence in Teaching Award at Michigan State, the Texas State Mathematics Department and College of Science Teaching Award, and is a 2009 Presidential Teaching Award nominee. Dr. McCabe and Dr. Sorto often work together on research for Mathematics Education. Dr. Sorto, who has a PhD from Michigan State University in the field of Mathematics and Statistics Education, took an interest in my idea and accepted when I asked her to be my thesis supervisor. And that is where it all began….

Review of Literature

Research Related to Problem Solving

According to ***Adding it Up: Helping children learn mathematics***, by the National Research Council, for a student to be proficient in mathematics five components must be accomplished: conceptual understanding, procedural fluency, strategic competency, adaptive reasoning and productive disposition (2001). For the purposes of this research we focus mainly on strategic competency and adaptive reasoning. Strategic competence refers to a students' ability to formulate mathematical problems, represent them and then solve them. This process is most commonly known as mathematical problem solving (National Research Council, 2001). According to the National Council of Teachers of Mathematics (2000), problem solving "is the hallmark of mathematical activity and a major means of developing mathematical knowledge" (p.116). Adaptive reasoning leads to what we will later discuss as metacognition, or the ability to think about ones' own thinking.

A vast amount of research has been conducted in the area of mathematical problem solving. Problem solving, which is considered to be the core of most mathematics curricula, is a cognitive process directed at achieving a goal when no solution method is obvious to the problem solver (Yunus & Ali, 2008). The *Principles and Standards for School Mathematics*, specifies that schools should enable students to accomplish the following: build new mathematical knowledge through problem solving, solve problems that arise in mathematics and in other contexts, apply and adapt a variety of appropriate strategies to solve problems and monitor and reflect on the process of mathematical problem solving (NCTM, 2000).Different elements of teaching and learning problem solving have been developed and generalized by mathematics educators. We will present and discuss the main aspects of those mentioned most commonly in the literature. Of the literature reviewed, we have determined that there are four basic elements of problem solving. These elements include content understanding, problem solving strategies, metacognition and motivation (Yunus & Ali, 2008). Each of these components is responsible for different parts of the problem solving process. For the purposes of our research we will first discuss the different problem solving strategies and then the use of metacognition.

Research of Problem Solving Approaches

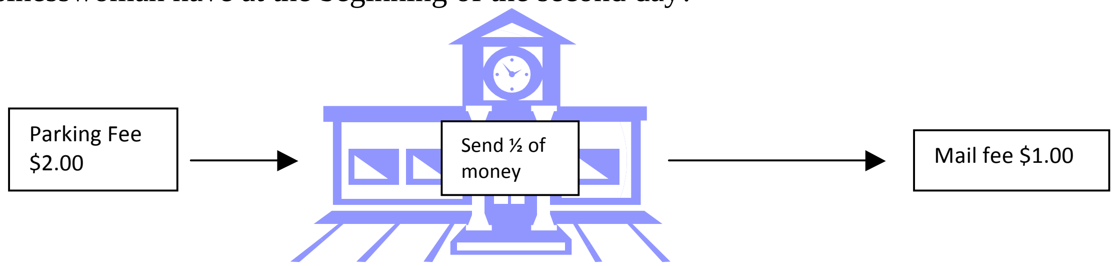
Problem solving strategies have been a controversial issue in the field of mathematics for many years. Some mathematicians believe that general problem solving processes must be taught, while others emphasize the need for more problem specific strategies. There are basically two categories of classification for problem solving in the field of mathematics; those that are aligned with the teachings of Polya, and those that are not. The first category stems from the work of George Polya. Polya was a researcher, author and teacher whose methods greatly affected the way we teach problem solving today. He wrote three books that dealt with problem solving in mathematics titled, *How to Solve It (1945), Mathematics and Plausible Reasoning (1954)* and *Mathematics Discovery (1965)* (Passmore, 2007). It was Polya's opinion that the main point of mathematics education should be to teach problem-solving methods (Polya, 2002). He developed a four-step process which specified that students must first understand the problem, chose a suitable strategy for solving it, use the strategy and then evaluate it. Polya also emphasized heuristics such as Drawing a Diagram, Working Backwards or Finding a Pattern to reach a solution to a problem (Passmore, 2007). Many math educators agree with Polya; however, they focus mostly on the second step of the problem solving process. Darin Beigie, states that the second step of Polya's process is the key ingredient in the problem-solving experience (2008). His research addresses the integration of content to guide the problem solving process. Beigie's studies have shown that students who perform better on traditional tasks are also superior at combining distinct procedures to solve a new and more difficult problem (2008). This suggests that better teaching of content could also be a method to improve problem solving skills; however mastering content does not always indicate that students truly understand what they are doing (Beigie, 2008). Some other problem solving strategies that stem from Polya are the guess and check method, considering a simpler case, making a table, chart or list, looking for patterns, using logical reasoning, acting out the problem, working backwards or using the process of elimination (Beigie 2008). An example of Polya's four step process being put into action is shown below. This example comes from a book used to teach pre-service teachers how to incorporate problem solving in the classroom (Bennett & Nelson, 2004). This problem (*Box 1*) uses both the heuristics of drawing a diagram and working backwards.

Box 1. Example problem adapted from *Mathematics for elementary teachers: a conceptual approach* *(2004).*

Problem: A businesswoman went to the bank to send half of her money to a stockbroker. She paid a $2.00 parking fee before entering the bank. Once inside the bank, she sent half of her money to the stockbroker. On the way out she was required to pay a $1.00 mail fee. She did not spend any more money that day. On the second day she returned to the bank and had to pay the $2.00 parking fee before entering the bank to send half of her remaining money to the stockbroker. Once again, on the way out she had to pay a $1.00 mail fee. If she had $182.00 left, how much money did she have before the trip to the bank on the first day?

Understanding the Problem: Let's begin by guessing the original amount of money, say, $800.00, to get a better feel for the problem. Question 1: If the businesswoman begins the day with $800.00, how much money will she have at the end of the first day, after paying the parking fee before entering the bank, giving half of her money to the stockbroker and then paying the mail fee as she is leaving?

Devising a Plan: Guessing the original amount of money is one possible strategy, but it requires too many computations. Since we know the businesswoman has $182.00 at the end of the second day, a more appropriate strategy for solving the problem is to retrace her steps back through the bank. First, she receives $1.00 back from the mail fee. Continue to work back through the second day in the bank. Question 2: How much money did the businesswoman have at the beginning of the second day?



Carrying Out the Plan: The businesswoman had $368.00 at the beginning of the second day. Continue to work backward through the first day to determine how much money she had at the beginning of that day. Question 3: What was this amount?

Looking Back: You can now check the solution by beginning with $740, the original amount of money, and going through the expenditures for both days to see if $182.00 is the remaining amount. The problem can be varied by replacing $182.00 at the end of the second day by any amount and working backward to the beginning of the first day. Question 4: For example, if there was $240.00 at the end of the second day, what was the original amount of money?

Answers to Questions 1-4:

1. $398.00

2. The following diagram shows that the businesswoman had $368.00 at the beginning of the second day.

   End of day 2 — Beginning of day 2

   $182.00 → $183.00 → $366.00 → $368.00

   Receive $1.00 mail fee. — Receive ½ of money sent. — Receive $2.00 Parking fee.

3. The diagram shows that the businesswoman had $740.00 at the beginning of the day, so this is the original amount of money.

   End of day — Beginning of day 1

   $368.00 → $369.00 → $738.00 → $740.00

   Receive $1.00 mail fee. — Receive ½ of money sent. — Receive $2.00 Parking fee.

4. $972.00

Another alteration of Polya’s techniques is suggested by Dr. Richard Lesh and Dr. Judith Zawojewski. They propose using Polya’s heuristics as a language to help problem solvers reflect on how they solved previous problems, rather than as a list of techniques they should use (2007). In other words, by introducing the students to the terms guess or draw a diagram, students can identify what they have done in the past and try to determine if it will work again. Koichu, Berman and Moore tested a similar idea known as heuristics literacy (2007). They defined heuristic literacy as not only the use of heuristic vocabulary, but also the internalized heuristics used in the actual task of problem solving (Koichu, Berman & Moore, 2007). They found the development of heuristic literacy and mathematical achievement were correlated with respect to students’ scores on the SAT (Koichu, Berman & Moore, 2007).

In contrast to Polya, some researchers have determined that introducing students to heuristics is often not effective for improving problem solving abilities. Schoenfeld claims that teaching the heuristic strategies proposed by Polya are much too general because each problem requires a unique approach and application of problem solving methods (1985). Therefore the students must not only learn the different heuristics but also all of the possible ways they can be altered. Lesh and Zawojewski drew the conclusion that short lists of heuristics such as Polya’s are too general, yet creating long lists of situation specific processes becomes so tedious that learning when and how to use all of the strategies would become the heart of problem solving instruction (2007). Lester makes the claim that teaching students about problem solving strategies or heuristics actually does little to improve their ability to solve problems (1994).

After reviewing the research, one important factor that has been left out of problem solving strategies is brain hemispheric dominance. Hemispheric dominance refers to a concept known as hemisphericity, which specifies that an individual processes information primarily through the left hemisphere or the right hemisphere or a combination of both (explained in detail below) (Saleh, 2001). According to the hemisphericity research in relation to cognitive styles, it appears that some of the general heuristics/problem specific strategies are more closely aligned with one hemisphere of the brain than the other. Has a possible relationship between brain-dominance and problem solving strategies been overlooked? Identifying this relationship could help mathematics educators improve the teaching and learning of problem solving.

Research Related to Metacognition

Taking the focus back to the four elements of problem solving and mathematical proficiency, we now shift to a focus on metacognition. Several studies have shown that metacognition greatly impacts an individual's ability to solve problems efficiently. A study by J. H. Hartman (1998) suggests that metacognition affects acquisition, comprehension, retention and application of what is learned. It also affects learning efficiency, critical thinking and problem solving. Metacognition is the skill that enables students to monitor their thought processes and determine their strengths and weaknesses with respect to problem solving (Yunus & Ali, 2008).

According to Flavell, metacognition refers to “one’s knowledge concerning one’s own cognitive processes (1976).” A study conducted by Yunus and Ali (2008) concluded that metacognition scores can predict, to a certain extent, achievement. A study by Kramarski, Mevarech and Arami (2002) concluded that students who had been exposed to metacognition instruction in a mathematics lesson significantly outperformed those who were not, on standard tasks and authentic tasks. In addition to this finding, they also determined that those students had been introduced to metacognition instruction were better at justifying their answers and the techniques they used (Kramarski, Mevarech &Arami, 2002). According to Passmore, metacognitive training, which encourages self-regulation, should be combined with approaches such as Polya’s to achieve successful problem solving (2007). If we combine the use of metacognition with knowledge of brain hemisphericity and problem solving strategies aligned with that hemisphericity, it could better equip students to solve more in depth mathematical problems.

Research Related to Hemisphericity and its Relation to Problem Solving and Metacognition

Now we shift the focus to the tool of metacognition and problem solving, the brain. The concept of complementary specialization refers to the idea that each hemisphere of the brain is specialized for different functions. It has not always been understood that each side of the brain was responsible for different functions. In fact, for a period of time it was even believed that the left side of the brain was dominant and that the right side of the brain was considered to be the minor side (Springer & Deutsch, 1998). We now know that both sides of the brain are equally important, only they specialize in different tasks. The human brain is split into two hemispheres which communicate via the corpus callosum. In terms of cognitive styles, it is generally accepted that the left hemisphere of the brain deals primarily with verbal, sequential, temporal and digital characteristics. It is also speculated that the left hemisphere is responsible for logical, analytical and rational thought. The right side of the brain is most commonly characterized as nonverbal, visuospatial, simultaneous, spatial and analogical. Types of thinking that are typically associated with the right hemisphere include synthetic, Gestalt and intuitive thought (Springer & Deutsch, 1998). Gestalt thinking refers to the viewing of things we see as whole forms, instead of individual parts that make up the whole. Research by Iaccino, refers to the differences in hemispheric functions as simply left-analytic versus right-holistic modes of information processing (1993). Left-analytic mode of thinking refers to the breaking down of information into separate components. These separate components are then processed individually in a very orderly fashion. The right-holistic mode of thinking is productive in distinguishing patterns of relationships between parts of a stimulus array, integrating many inputs simultaneously and arriving at complete configuration (Iaccino, 1993). From this information we can see that approaches to problem solving might differ with respect to which side of the brain in which a person is more dominant. Understanding that each hemisphere incorporates a different cognitive style, leads to the idea of hemisphericity. Hemisphericity refers to the concept that an individual processes information primarily through the left hemisphere or the right hemisphere or a combination of both (Saleh, 2001). In many cases an individual relies on one hemisphere of the brain more than the other. The idea that a person has a more dominant hemisphere has many further implications. Individual, occupational, cultural and educational preferences are all possible areas that are affected by brain hemisphericity (Iaccino, 1993). For example, left-moders are described as more logical and rational whereas right-moders are more imaginative and creative. With respect to occupation and education, a study done by Amany Saleh revealed a correlation between brain hemisphericity and choice of major (2001). The results from this research study showed that students majoring in arts, literature, education, communications, nursing and law were found to be right-brain dominant, whereas students majoring in business, engineering and science showed left-brain dominance (Saleh, 2001). These findings provide information that could be useful for educators in the future. Administrators and teachers in middle schools, high schools and colleges could use knowledge of a student's hemisphericity to help guide them into career and educational paths in which they would excel. Knowledge of a child's hemisphericity could also help teachers to better accommodate students needs in the classroom. Studies have shown that students who are taught through methods that correspond with their hemispheric style achieved higher test scores (Saleh, 2001). Substantial amounts of research also indicate that to maximize learning, the left and right hemispheres must work harmoniously. To amplify and unite the knowledge of left and right brain characteristics to achieve whole brain instruction is the current focus of many educators (Respress & Lutfi, 2006). Educators could help students achieve this harmonious relationship by using teaching strategies that are both categorized as right brain dominant and left brain dominant. A researcher by the name of Bernice

McCarthy, felt so strongly about the importance of hemisphericity in education that she developed an instructional cycle that provided right-brain oriented instruction and left-brain oriented instruction called the 4MAT (Scott, 1994). Her lesson cycle combined both the concepts of brain hemisphericity and Kolb's model of learning styles. The identified learning styles show that students either perceive concretely or abstractly and process actively or reflectively (Scott, 1994). Based on these conditions there are four different learning styles. In McCarthy's model, she addresses each learning style as well as both hemispheres of the brain. In all this creates eight different ways of processing information, and McCarthy believed that each lesson should include activities to meet the needs of each specific learner (McCarthy, 1990). Thus, she developed the 4MAT cycle which includes eight different activities to complete a lesson cycle and encourages students to feel comfortable working in all style of thinking (McCarthy, 1997). Incorporating a good variety of learning styles when teaching can help meet the needs of every student, as well as encourage the use of both hemispheres harmoniously.

The next question that arises is how do we test for hemisphericity? There are several measures that are used to classify an individuals' hemisphericity. Some tests involve the use of neuroimaging to identify patterns of activity in the brain while the subject is performing some type of mental operation (Springer & Deutsch, 1998). Another test uses visual stimuli to determine the differences in the ways individuals perform on half-field presentations (Springer& Deutsch, 1998). As we have already determined from previous research, the left side of the brain controls the right side of the body and the right side of the brain controls the left side of the body. This also applies to the visuals fields of each eye. The assumption of this study is that performance will be superior when a stimulus is presented initially to the visual field of the hemisphere specialized for processing it (Springer & Deutsch, 1998). A final, yet less common, method of testing for hemispheric dominance is by paper-and-pencil measures (Albaili, 1996). Of the few paper-and-pencil tests that have been developed to assess cognitive style or hemisphericity in students, perhaps the most popular is the Style of Learning and Thinking developed by Paul Torrance. This questionnaire "is a standardized measure of left-right thinking style" (Liao & Chuang, 2007). According to the Mental Measurements Yearbook, the SOLAT is commonly used for determining a student's brain hemisphere preference and learning style with respect to problem solving (Torrance, 1988). The results of this test are used to determine if a student is more left-brain dominant, right-brain dominant or whole-brain dominant. Further information on this test will be included in the methods portion.

As far as the field of mathematics education is concerned, there is still much research to be done in the area of problem solving. As stated in the Second Handbook of Mathematical Research, the amount of research on problem solving has declined in recent years (Lesh & Zawojewski, 2007). It is clear that for students to be successful in mathematical problem solving, they must have both Strategic Competencies and Adaptive Reasoning skills (National Research Council, 2001). Although we still have not determined the best method for teaching problem solving, we have determined that metacognition must play a role. One tool in the use of metacognition could be the application of hemisphericity and its implications in the problem solving process. It is clear that hemisphericity has an impact on learning styles. It is suggested that differential utilization of the hemispheres reflects an individuals' cognitive style, which is their preference to an approach for problem solving. According to Springer & Deutsch (1998), "A tendency to use verbal or analytic approaches to problems is seen as evidence of left-side hemisphericity, whereas those who favor holistic or spatial ways of dealing with information are seen as right-hemisphere people "(pg. 294). Examples of the various methods students use to reach a solution to the same problem are provided below. This problem comes from another book, titled _Thinking through Mathematics_, which is used to help pre-service teachers learn how to teach inquiry and problem solving skills in the classroom (1990).

> Problem (2): In the barnyard, I have some chickens and some rabbits. I count 50 heads and 120 legs. How many of each type of animal is in the barnyard?

Figures 1.1 to 1.7 represent different student created responses to problem (2).

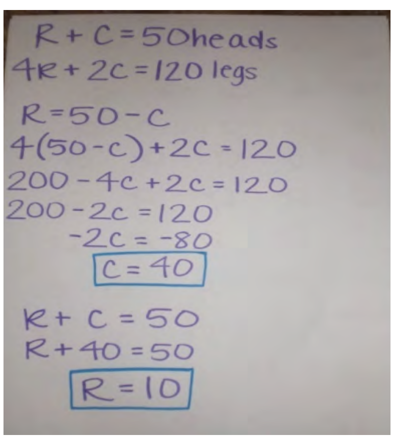


*Figure 1.1.*Algebraic approach to solving the problem.

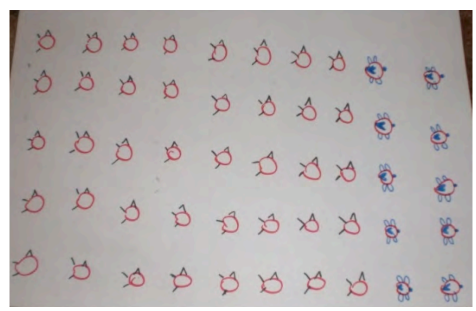


*Figure 1.2.*Visual approach to solving the problem.

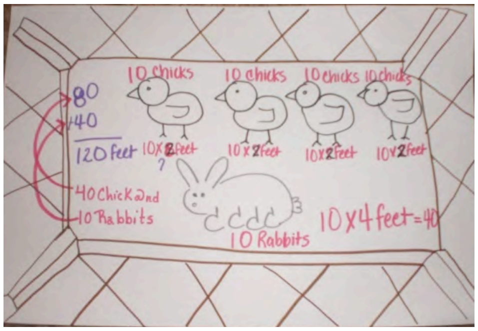


Figure 1.3. Visual approach to solving the problem combined with guessing and checking.

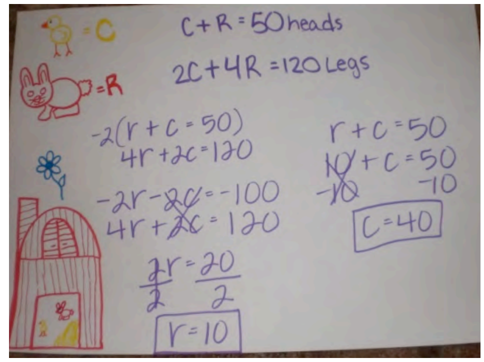


Figure 1.4. Algebraic approach to solving the problem, different from the *Figure 1.1*.

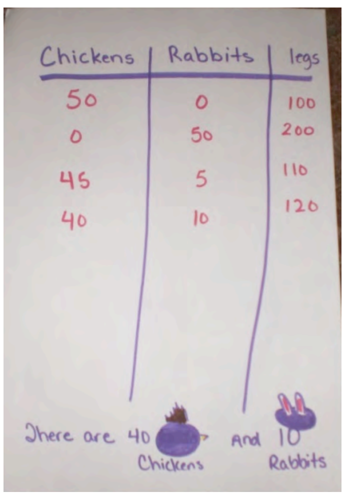


Figure 1.5. Using a table/ chart to solve the problem.

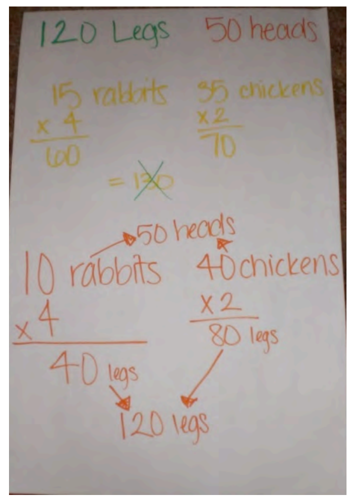


Figure 1.6. Guess and check approach to solve the problem.

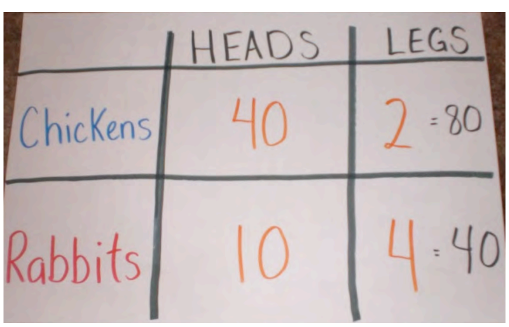


Figure 1.7.Using a table/chart different than, *Figure 1.5* to solve the problem.

As we can see there are many different ways to solve the same problem. Each student approached the problem differently and still arrived at the same answer. The differences in the methods used to solve the problem are a result of the students' different learning styles and hemisphericity. If we can increase the amount of metacognition instruction our students receive by using the knowledge of how hemisphericity impacts mathematical problem solving, it will only aid in the improvement of problem solving abilities. I will seek to identify the different methods used to reach a solution to a mathematics problem and their relation to a students' hemisphericity. I hypothesize that students who use methods such as tables, charts, lists, logical reasoning, and process of elimination to solve the problem will show a left hemispheric dominance when tested. I also hypothesize that students who use techniques such as draw a diagram, guess and check, look for patterns, act out the problem or work backwards to solve the problem will display right hemispheric dominance when tested. The results of this exploratory study will provide more information as to how hemisphericity relates to mathematics problem solving and how we could eventually achieve the harmonious use of both hemispheres.

Methodology

Conceptual Framework

This study will seek to find the relationship between students' brain hemisphericity and preferred strategies to solving a mathematics problem. To determine any association that brain hemisphericity might have for mathematics education, we must measure these two constructs and identify if any relationship exists. Brain hemisphericity refers to the concept that an individual processes information primarily through the left hemisphere or the right hemisphere or a combination of both (Saleh, 2001). With respect to cognitive styles, it is generally accepted that the left hemisphere of the brain deals primarily with verbal, sequential, temporal and digital characteristics. It is also speculated that the left hemisphere is responsible for logical, analytical and rational thought. The right side of the brain is most commonly characterized as nonverbal, visuospatial, simultaneous, spatial and analogical. Types of thinking that are typically associated with the right hemisphere include synthetic, Gestalt and intuitive thought. (Springer & Deutsch, 1998). Further research suggests that the specialization differences should be referred to as left-analytic and right-holistic modes of information processing (Iaccino, 1993). Students' brain hemisphericity will be sought through a non-invasive method. In turn, these cognitive styles can also be associated with preferred strategies by students when solving mathematical problems with any constraints.

A preferred strategy refers to a student's choices in response to a non-standardized open ended mathematics problem. George Polya, the pioneer of problem solving education, specifies that students use many different heuristics to solve problems. Some of these heuristics include Drawing a Diagram, Working Backwards or Finding a Pattern to reach a solution to a problem (Passmore, 2007). Some other problem solving strategies that stem from Polya are the guess and check method, considering a simpler case, making a table, chart or list, looking for patterns, using logical reasoning, acting out the problem, working backwards or using the process of elimination (Beigie 2008). The method a student chooses to use is their "preferred strategy."

The relationship between brain hemisphericity and students' preferred strategies is depicted according to the following framework (*Figure 2*).

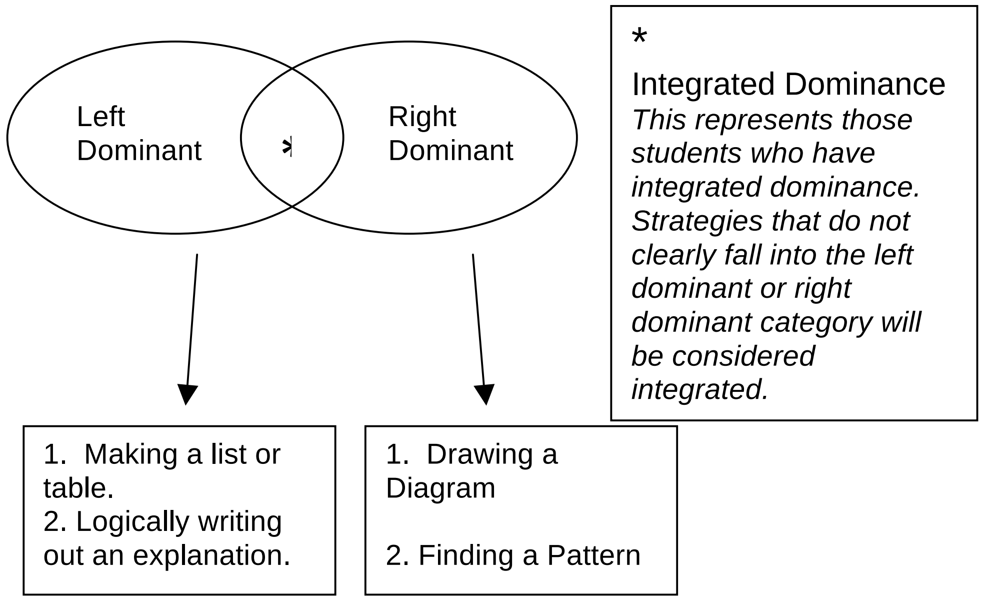


Figure 2. Conceptual Framework

The two ovals represent the two hemispheres of the brains and their intersection represents the use of both hemispheres. It is hypothesized that the left brain dominance is associated with solving strategies such as making a list or table and logically writing out an explanation since the left hemisphere is responsible for logical, analytical and rational thought (Springer & Deutsch, 1998). Furthermore, it is hypothesized that the right brain dominance is associated with drawing a diagram and finding a pattern since nonverbal, visuospatial, simultaneous, spatial and analogical are types of thinking that are typically associated with the right hemisphere (Springer & Deutsch, 1998). Lastly, the integrated dominance is expected to be associated with responses that incorporates one or more methods from each the left brain and right brained dominant categories or if the method does not fall into either of the categories.

Analytic Framework

Population and sample

The population for this study is made up of 622 ninth grade students from a High School in Southeast Texas. Of the 622 students, 63% are Caucasian, 25% are Hispanic, 8% are African American, 3% are Asian/Pacific Islander and 1% are Alaskan/Native American. Out of these students, 9% are considered Special Education and 19% are considered Economically Disadvantaged. Most of these students previously attended five different intermediate schools. The scores from the math portion of the 2008 Texas Assessment of Knowledge and Skills tests are provided below (*Table 1)* for the five intermediate schools which contribute to this population. These test results show that the population from which we are drawing our sample is very competent in the area of mathematics.

Table 1
Intermediate TAKS Data 2008

Intermediate School	Number Tested	Percent Passed	Percent Commended
School A	351	94	31
School B	324	97	46
School C	355	100	56
School D	426	98	48
School E	292	96	34

Of the 622 freshman students that attend this school, a sample of 98 is being tested for the data collection of this study. These 98 students are randomly selected by their advisory class. Advisory is a class that all students attend for 30 minutes, one time a week. This advisory acts as the students "homeroom," giving them important school and testing information. The students are randomly placed in advisories, and the seven advisories chosen for this study were selected at random as well. Although this sample is greatly representative of the population, one group of students was excluded from the study. Advisory classes which contain at risk students are excluded from the study for various reasons given by the administrators of the school. The demographic information for the sample is provided in the tables below.

Table 2
Student Sample Age

Number of Students	**Age**
32	14
60	15
6	16

Table 3
Student Sample Gender

Male	**Female**
48	50

Table 4
Student Sample Ethnicity

Ethnicity	**White**	**African American**	**Hispanic**	**Asian**	**Other**
Number of Students	52	8	26	4	8
Percent of Students	53%	8%	27%	4%	8%

The sample only varies slightly in their mathematics experience. A total of 65% percent of the students in the sample are currently taking Algebra I. The remaining 35% of students are either enrolled in Regular/Advanced Geometry or Regular/Advanced Algebra II. Of these students 22% identify themselves as English Language Learners and 36% identify themselves as Gifted and Talented.

Data Collection

The students are being tested during two different advisory class periods. At each testing protocol, the students will receive a copy of the Consent and Assent

Forms (see Appendix B) as required by the Institutional Review Board. During the first advisory class period, the students will be filling out a demographic questionnaire and solving the mathematical problem. The demographic information is described in the sample above. The final advisory class session is used for the students to complete the Style of Learning and Thinking Questionnaire (see Appendix C for a copy of the instruments). These three items are only connected by a number to maintain anonymity. Teachers will record each student's number to ensure that data for each student is kept together through this collection process. Upon completion of all three tasks, the advisory teachers will destroy any identifying information, such as the names accompanied with the numbers on the instruments. The sample is split in to seven different advisory classes, in which each teacher will read word for word directions for the administration of the instruments (see Appendix D for teacher instructions).

Variable Measurement and Methodology

To measure these two constructs, two different instruments are used. The first instrument is used to determine students' brain hemisphericity. In 1988, Dr. Paul Torrance developed a questionnaire known as the Style of Learning and Thinking (SOLAT). This questionnaire is designed to help determine a students' dominance in either the left cerebral hemisphere, right cerebral hemisphere or the integration of both. The questionnaire is a series of 28 non-invasive questions that help distinguish hemispheric specialization.

The second instrument is a non-standardized math problem, which has been proven to elicit different methods for solving (T. McCabe, personal communications, March 11, 2009). The responses to this problem are then categorized by a scale that has been developed based on theory (see *Figure 2. Conceptual Framework* above). The categorization of these responses helps to identify any correlation relationship between the preferred strategies and the SOLAT results.

Instruments

SOLAT

The initial version of the SOLAT was intended to be used to test adults. It originally consisted of 50 items that were based on research findings in reference to specialized functions of the left and right hemispheres. Each item on the original SOLAT had three possible responses for the subject to select. The first response was representative of left specialization, while the second response was representative of right specialization. The third response on this version was left available for subjects who showed an integration of the hemispheres for a particular question. The initial test of the first version of the SOLAT was given administered to 78 graduate students. The results showed that there was much ease in completing the 50 items in about 15 minutes. Analysis of the three scales (left, right and integrated) revealed that almost all of the items had satisfactory correlation coefficients. Items that had marginal or submarginal internal consistency were eliminated, leaving only 36 items to which four more were added later to arrive at a total of 40 questions for the adult version. Several attempts have been made to adapt the adult version into a youth version. Many of these attempts involved simplifying the vocabulary to a level that children and youths would understand. However, Bernice McCarthy along with Jamie Smith assisted in adapting the test to represent situations that were within the behavioral repertoire of children (Torrance, 1988). Mary Kolesinski also assisted these researchers in making further adjustments for the youth version of the test. In the development of both the Elementary and Youth forms, standard procedures were followed. Each initial version consisted of 50 items. The test items were checked against cumulative research on hemispheric specialization. The 50 question surveys were given to 400 children in grades K through 5 and 1,000 in grades 6 through 12. After thorough analysis, the tests were reduced to 25 items for the Elementary version, and 28 items for the Youth version (see Appendix C for a copy).

The testing environment for the Youth form of the SOLAT is designed for a classroom setting. A good testing setting must be arranged and maintained throughout testing. During the administration of the SOLAT, the students will be in their advisory classrooms. The advisory classrooms are the location in which all testing is completed for this particular school. This ensures a good testing environment which will easily be maintained. The testing process is thoroughly explained to the students. For each item, there are two statements and four different ways to respond. Students can either check the first statement if describes them, check the second statement if it describes them, check both statements if they feel that both apply, or check neither statement.

Scoring this test is fairly straight forward. The tests are marked on paper which has a carbon key attached. After they are turned in, using the carbon key, the number of L's (Lefts) and the number of R's (Rights) and the number of statements in which both were checked (Whole-Brained) are counted and totaled. A tally is also made of the items that were left blank. These numbers represent the Raw Scores and are recorded on the Profiles Form. The Raw Scores are then converted to Standard Scores and Percentiles by using the conversion table provided with the Profile Form. These Standard Scores and Percentiles were calculated on the actual distribution of the Raw Scores and do not follow the "normal curve." This percentile ranking is used in conjunction with the preferred strategies responses to determine if there is any correlation.

Mathematics Problem

The problem that is being used to elicit the students' preferred strategy has been used in several similar research studies. This type of mathematical problem allows for variation in the methods used to solve it and has proven to have many different strategies to achieve the correct answer. The problem is stated below in *Box 2* and is also in Appendix C.

Box 2. Mathematics Problem

Instructions:
Please show how you would answer each of the following problems by using the first method that comes to you. It is very important to show (on this paper) how you are thinking of the problem and your thought process. Having the correct answer is not the focus of this exercise. We want to see the way you think about the problem.
Problem:
A High School is hosting a round robin soccer tournament, in which each team must play every other team once. For each of the following numbers of teams, please indicate how many total games would be played. I should be able to look at your work, and determine the number of games for each situation.

2 teams

3 teams

4 teams

5 teams

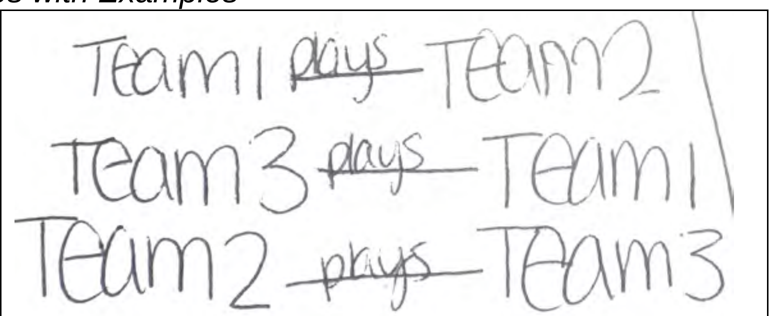
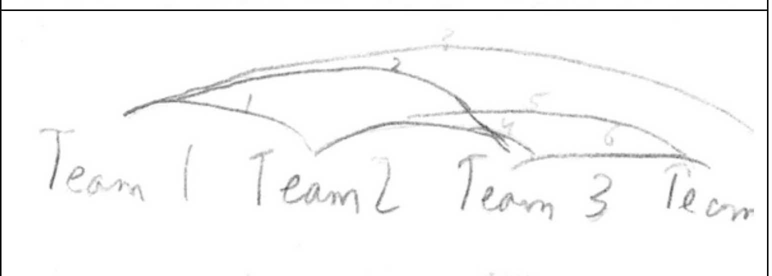
6 teams

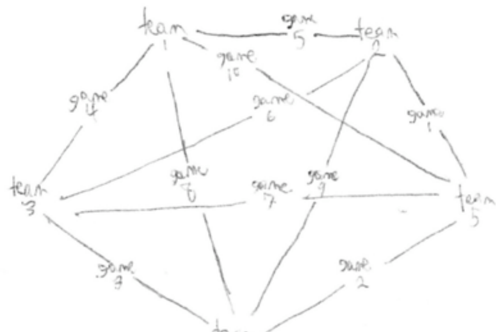
Have you solved a similar problem before? Yes No

Similar types of problems have been used several times in college classroom settings, as well as elementary classroom settings to test for problem solving methods (T. McCabe, personal communications, March 11, 2009). The most commonly used strategies for solving this type of problem are drawing a diagram, finding a pattern, making a list or table, or logically writing out an explanation. The students' responses to the first three portions of the mathematical problem are being used to assign each student to a category. It is important to use their initial responses because this is the best indicator of brain dominance. As the students continue working the problem they begin to analyze their method and might decide to change.

To characterize the responses, a common rubric is used. Each response has a label which corresponds to each of the solving strategies under consideration. See Figure 3 for the description and example of the strategies. More examples can also be found in Appendix E.

Figure 3. Coding of Responses with Examples

<u>Listing:</u> uses words or objects to list each game that will be played	
<u>Diagramed Listing:</u> listing the number of teams, but using connectors (lines/arcs) to represent each game	

Drawing a Diagram: uses shapes and connectors (lines/arcs) to account for each game	
Written Logical Explanation: uses words or phrases to describe what will happen	Well see, If there is two teams there's only gonna be 1 game A team can't play against itself (duh), so it's always one less than the # of teams
Blank: No response	

A statistical Analysis of Variance (ANOVA) is used to find the association between the SOLAT scores and the strategies used to solve the mathematics problem.

Results

The results for the mathematics problem and the SOLAT are presented separately, followed by the comparison of the two. To examine information from the mathematical problem a simple frequency chart was used, and a T-test with mean 50 was used for examination of the distribution of the SOLAT scores. ANOVA was used to analyze the comparison of the mathematics problem with the SOLAT for the final results.

Mathematics Problem

The first step of analysis was to analyze the different methods that the sample group used to answer the mathematics problem. In the first examination of the methods used to solve the mathematical problem, we classified the responses into nine different categories. To ease the analysis process, we created numerical codes corresponding to each category. The numerical codes and categories were: 1- Listing, 2- Diagrammed Listing, 3-Vertical Diagram, 4- Positioned Diagram, 5- Written Logical Explanation, 6- Answer Only, 7- Other, 8- Blank/No Response, 9- Written “I Don’t Know”. The categories were later collapsed into the five responses discussed previously in the Methods section to analyze with the results of the SOLAT. The reason for this was that we want to test the hypothesis that certain methods of solving the mathematical problems are related with certain brain dominance. The mathematical problem required the students to respond to six different cases; one for each different number of teams involved in the tournament. The first case was to consider 2 teams; the next case was to consider 3 teams, and so on. *Figure 4* shows the frequency of the responses for each portion of the mathematics problem.

Figure 4. Frequency of Strategies Used to Solve Mathematics Problem

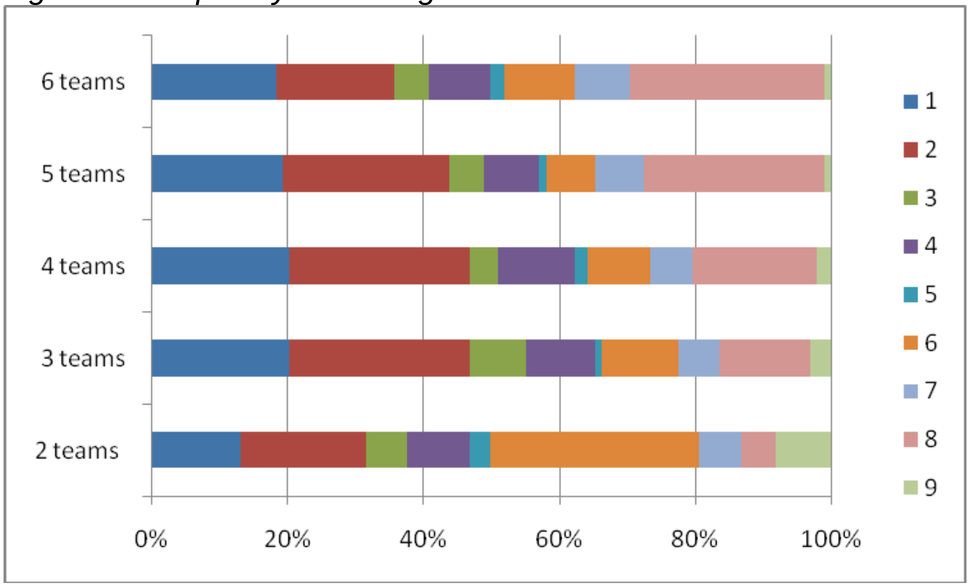
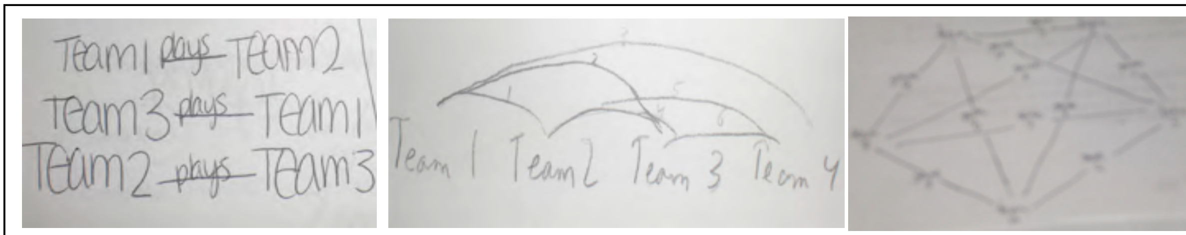


Figure 4. Response Key: 1-Listing, 2- Diagrammed Listing, 3-Vertical Diagram, 4-Positioned Diagram, 5- Written Logical Explanation, 6- Answer Only, 7- Other, 8-Blank/No Response, 9-Written "I Don't Know"

It is worth noting that the two most popular responses were Listing and Diagramed Listing for all cases except for the case of 2 teams. When answering the case of 2 teams, students preferred to just write the answer. The reason for this could be due to the fact that it is very simple to figure out the total number of games when there are only two teams. *Figure 5* shows examples of the most popular responses. These responses were used more often as the preferred strategy when the number of teams in the problem increased to 4, 5 and 6.

Figure 5. Listing, Diagrammed Listing and Diagram Responses



Listing | Diagrammed Listing | Diagram

SOLAT

The second step of analysis was to score the SOLAT results. After completion of the SOLAT, Raw Scores were converted into Standard Scores, which were then converted into Percentile Scores. These Percentile Scores indicated what percentage of students their age, they exceed in dominance for each the left, right and whole brain scales. Students could either score high on the Left Percentile, high on the Right Percentile, high on both, or high on the Whole Percentile. A high percentile score on both the left and right however, did not indicate whole brain dominance. *Figures 6.1, 6.2 and 6.3* represent the distribution of the percentiles from the SOLAT with respect to the typical ninth grade results. Each graph is accompanied by the mean and standard deviation of the distribution. Recall that a 50 on the percentile score corresponds to the median response expected from the typical ninth grader. Hence, to quantify the comparison of the observed brain dominance of the respondents to the “typical” ninth graders, a one sample T-test for each of the percentile scores was performed against the null value of 50.

Figure 6.1. Left Percentile Distribution

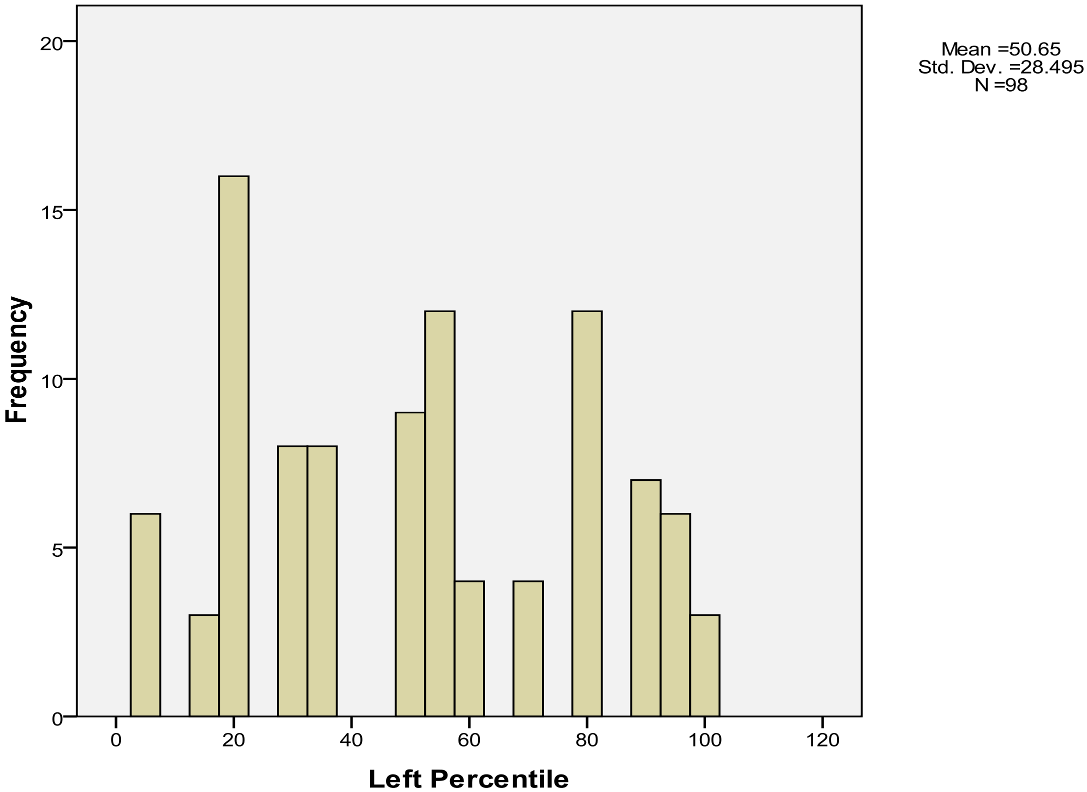


Figure 6.2. Right Percentile Distribution

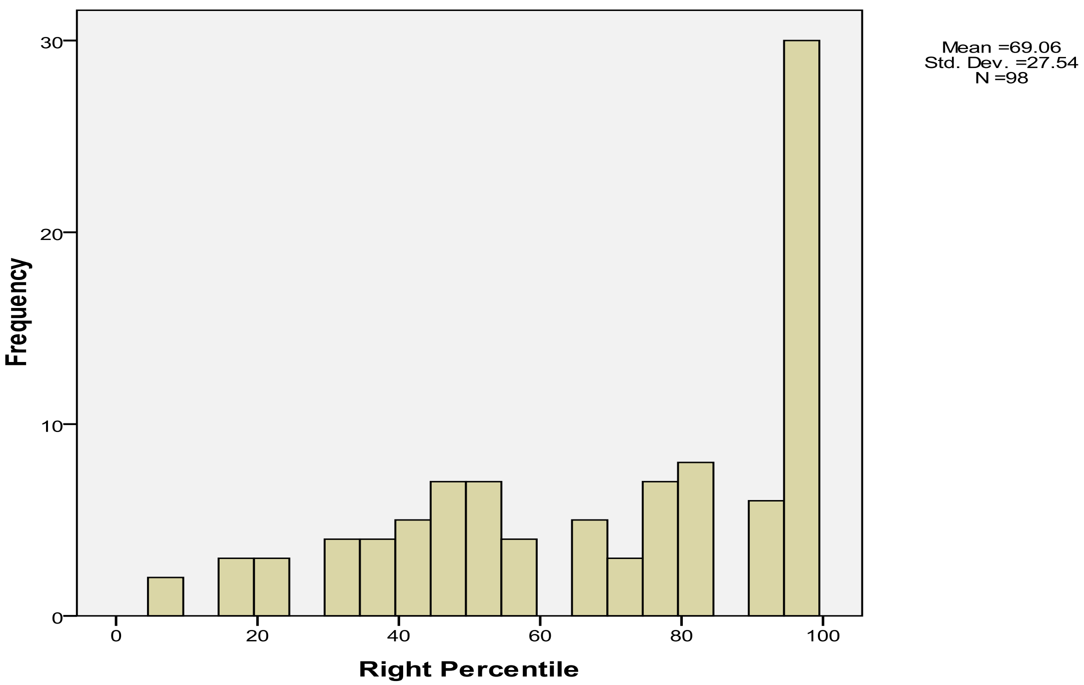


Figure 6.3. Whole Percentile Distribution

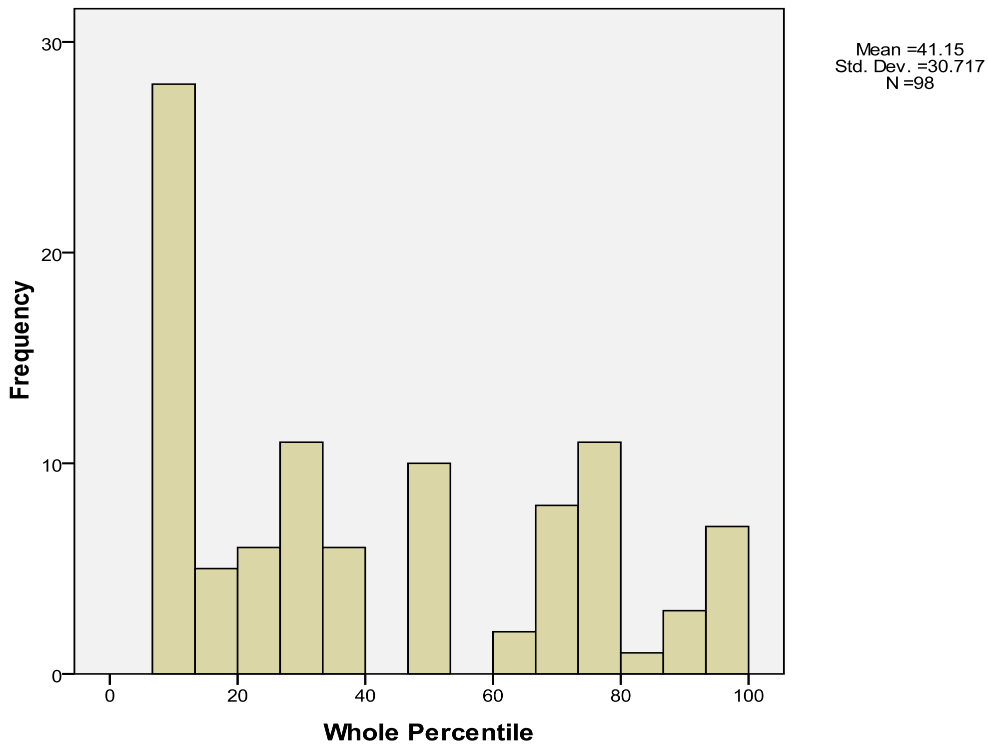


Figure 6.1 shows the percentile results for the SOLAT instrument associated with left brain dominance. As expected, the sample tested approximately normal for the typical ninth grade population, with mean 50.65 and standard deviation 28.49 and p=0.82. Hence, the respondents are typical of ninth graders. However, *Figure 6.2* which shows the percentile results for the SOLAT in association with right brain dominance shows a left skewed distribution than what is typically expected. The mean was 69.06 and the standard deviation was 27.54 and p<0.0001.This indicates that there was an abnormally large amount of the students in the sample who were classified as scoring high on the Right Percentile Scale. This abnormality in the sample could cause other abnormal results in the comparison of the Mathematics Problem Response and the SOLAT results. *Figure 6.3*, which shows the percentile results for the SOLAT instrument associated with whole brain dominance, is only

slightly inconsistent with that of the typical ninth grade population, with a mean of 41.15 and a standard deviation of 30.72 and p=0.0053.

ANOVA- Mathematics Problem and SOLAT

The relationship between the responses to the Mathematics Problem and the SOLAT results were analyzed using Analysis of Variance (ANOVA). ANOVA tests were performed for each case (2 teams, 3 teams, 4 teams, 5 teams, and 6 teams) versus percentile scores for left, right, and whole brain. Many ANOVA tests were conducted, and several tested to be significant. The results that are represented by *Figure 7.1* are for the case of 2 teams, whereas the results represented by *Figures 7.2 and 7.3* are for the case of 5 teams. Similar results (p-values) were found for other cases, but these specific cases presented the most significant results for one of each of the three percentiles; right, left and whole. Additional significant relationships can be found in Appendix A. Response labels correspond to the defined responses in *Figure 3* in the Methods section. Also, below each graph is a table which contains the information obtained by the Analysis of Variance (ANOVA).

Figure 7.1. Responses for 2 Teams in Relation to Right Percentiles

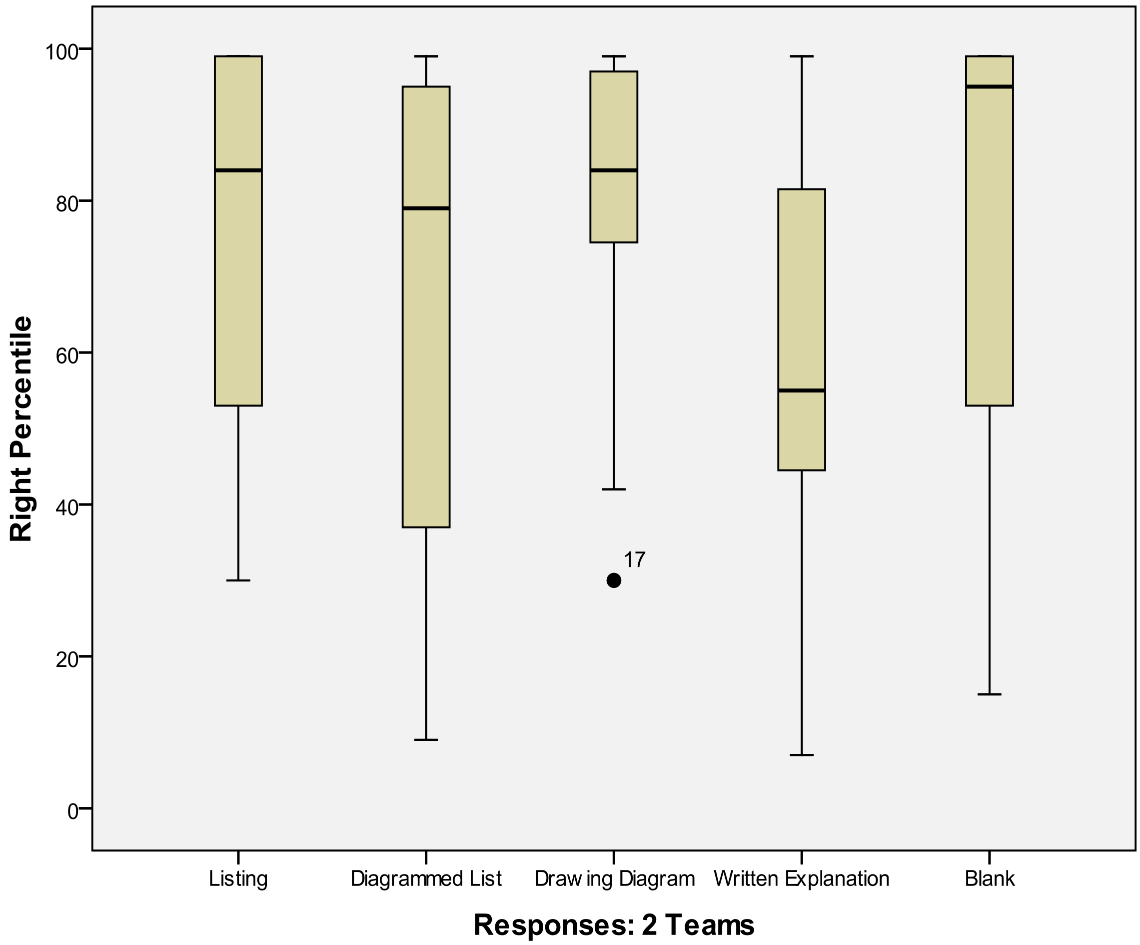


Table 5

Analysis of Variance for Right Percentile and Responses for 2 Teams

Source	DF	SS	MS	F	P
Groups	4	6464.33	1616.08	2.240	0.0707
Error	93	67107.3	721.58	--	--
Total	97	73571.6	--	--	--

The first result that stands out from *Figure 7.1* is the significant relationship (p=0.0707) among the problem solving strategies depending on right brain dominance. This result is strongly consistent with the original hypothesis. We can see that the students scoring high on the right percentile, most often responded to the 2 Teams portion of the Mathematics Problem, with either a Blank response, a Diagram or a List. The distribution of the Diagramming response is concentrated in the higher percentiles. This shows, as hypothesized, that students scoring the highest in the right percentile primarily used the Diagram strategy to solve the problem. However, the result of right brain dominant individuals using the Listing strategy is inconsistent with the hypothesis since this method is, in theory, associated with the left brain. A possible reason for this result could be the abnormal SOLAT results discussed previously. This particular sample had an abnormally skewed distribution for the number of students scoring high in the right percentile. Also, there was a group of students who scored high on both the right and left percentiles, which would explain this crossover result. But, we can see that the Listing strategy was more distributed than the Diagram strategy, which adds confidence to the conclusion that Diagramming was the preferred strategy for those scoring high in the right percentile.

Figure 7.2. Responses for 5 Teams in Relation to Left Percentiles

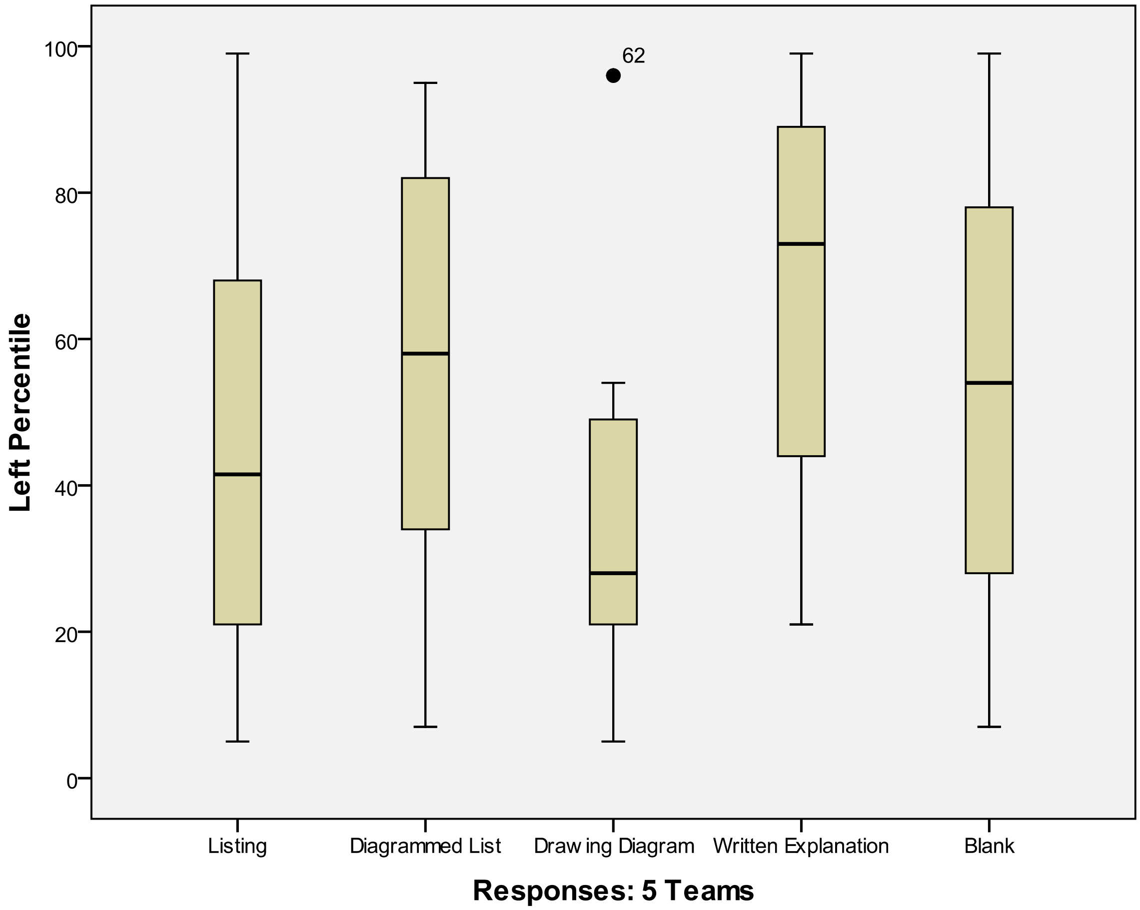


Table 6

Analysis of Variance for Left Percentile and Responses for 5 Teams

Source	DF	SS	MS	F	P
Groups	4	6584.79	1646.20	2.121	0.0843
Error	93	72173.4	776.06	--	--
Total	97	78758.2	--	--	--

Analysis of *Figure 7.2* showed another significant (p=0.0843) relationship among the problem solving strategies depending on left brain dominance. This result is also consistent with the original hypothesis to some extent. The diagram shows that students scoring high on the left percentile responded to the 5 Teams portion of the Mathematics Problem, most often with either a Written Logical Explanation response, a Diagramed List or a List. As hypothesized, students scoring high in the left percentile used a Written Logical Explanation response or a Listing method to solve the mathematics problem. Surprisingly, students scoring high in the left percentile also used Diagrammed Lists to solve the problem. This finding could be also attributed to the fact that the students could have been from the group that scored high on both the left and right percentiles of the SOLAT.

Figure 7.3. Responses for 5 Teams in Relation to Whole Percentiles

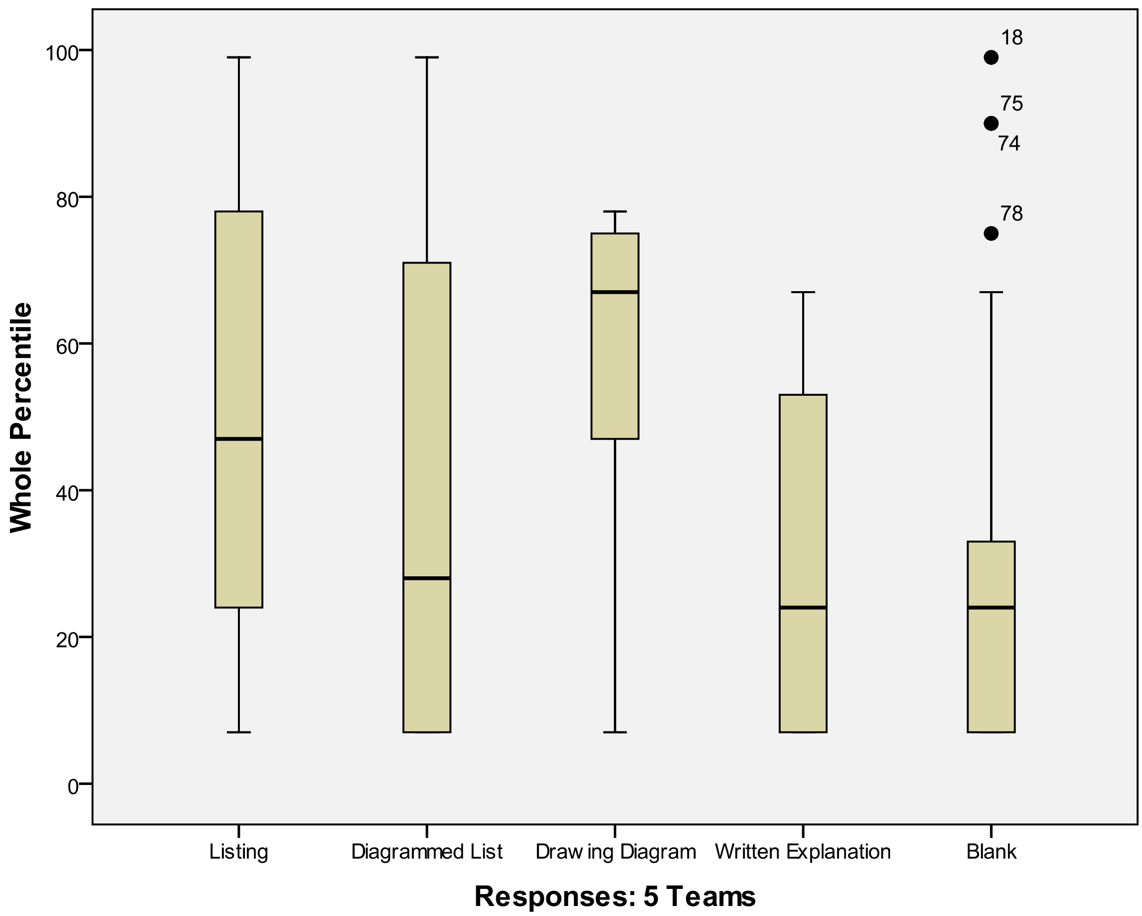


Table 7
Analysis of Variance for Whole Percentile and Responses for 5 Teams

Source	DF	SS	MS	F	P
Groups	4	8249.74	2062.43	2.303	0.0642
Error	93	83271	895.39	--	--
Total	97	91520.7	--	--	--

The final significant (p=0.0642) relationship, represented in *Figure 7.3*, was between the problem solving strategies depending on whole brain dominance. This result is consistent with the research; however we made no specific hypothesis for whole brain dominance. We can see that students scoring high on the whole brain percentile responded to the 5 Teams portion of the Mathematics Problem most often with either a List or a Diagram. Using the Conceptual Framework (*Figure 2*) as a guide, we can see that Listing is under the Left Dominant section and Diagrams are under the Right Dominant section. Therefore, students who tested to be high on the whole brain percentile used either a hypothesized left brain strategy or a hypothesized right brain strategy. This correlates with the idea that whole brain dominant individual's use either a combination of methods or sometimes choose a left brain dominant strategy, while at other times they choose a right brain dominant strategy.

Discussion

It was clearly identified through this research that several methods for solving a mathematics problem correlated with specific brain dominance. As hypothesized, students who tested high for left brain dominance tended to prefer a written, logical explanation strategy to solve certain levels of complexity of the mathematics problems. Also, as hypothesized, students who tested high in right brain dominance, tended to prefer drawing diagrams to solve certain levels of complexity of the mathematics problem. These two relationships show that the general characteristics associated with each hemisphere of the brain, also apply to mathematical problem solving.

A highly possible reason for the results that proved to be inconsistent with the hypothesis is the fact that this sample contained an abnormally large number of right brain dominant individuals. This could explain why the listing strategy tested to be a more right brain dominant strategy. Perhaps a more explicit brain dominance test could be used to more accurately classify the students as either right brain dominant, left brain dominant or whole brain dominant. The SOLAT allowed for students to score high on two percentiles, rather than eliminating two percentiles and having a final classification as left, right or whole brained. This could also have been a reason for the abnormal amount of students scoring high on the right percentile.

Recommendations

There are vast amounts of research in the field of mathematics education. However, the results of this study indicate that it could be beneficial for more research to be done in the area of relating brain hemisphericity to teaching mathematical problem solving. A possible step for future research could be to identify why the results were more significant for the more complex portions of the mathematics problem. Another interesting factor would be to determine if any correlation exists between a students' rating of mathematics and their brain hemisphericity or between their gender and hemisphericity. In addition to these investigations, a different method for testing brain hemisphericity, such as neuroimaging or visual field tests could be used. The results of these studies could have various implications for mathematics education. Most importantly, this information could be used to help develop more whole brained mathematical problem solvers, by teaching strategies that are associated with both hemispheres.

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Appendix A

Additional Results

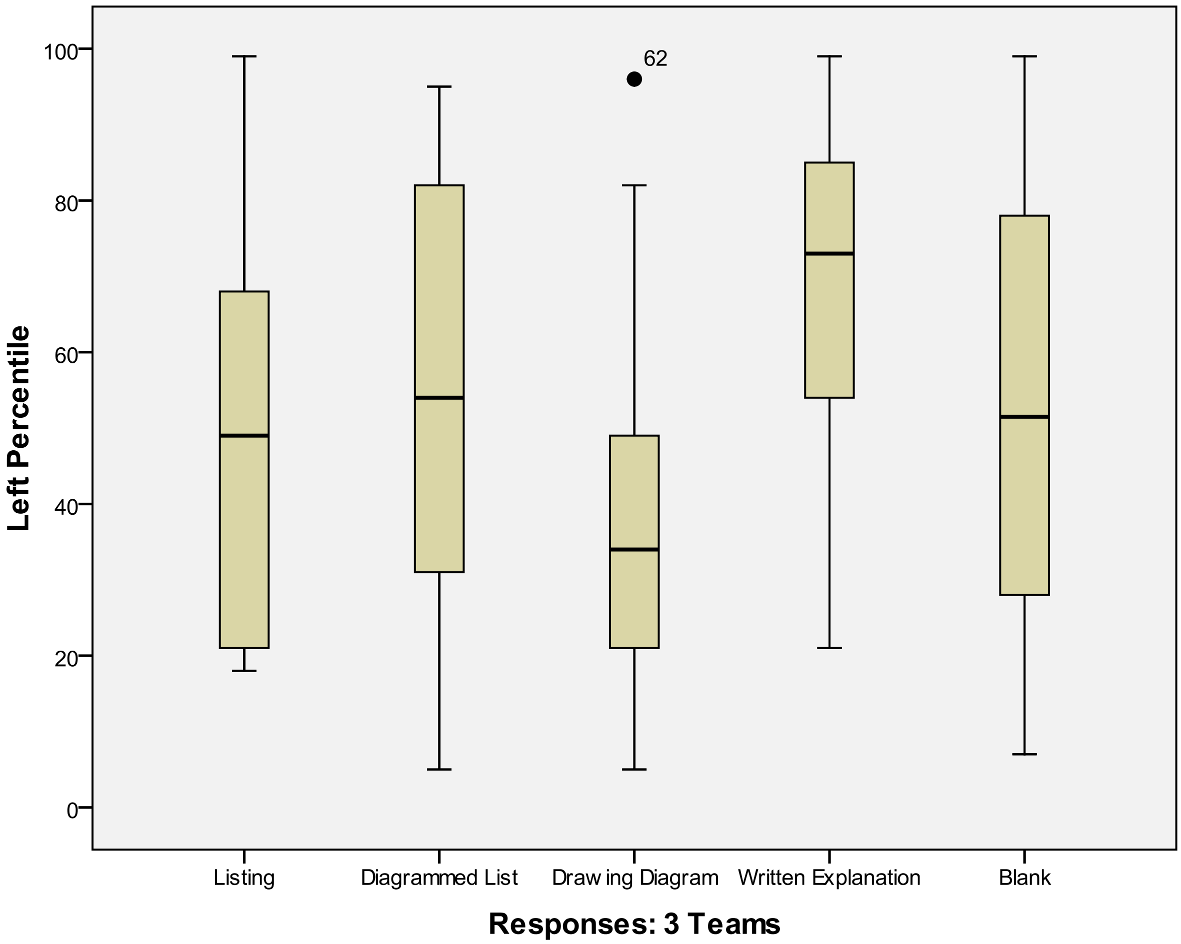

Table 8

Analysis of Variance for Left Percentile and Responses for 3 Teams

Source	DF	SS	MS	F	P
Groups	4	6575.6	1643.90	2.118	0.0847
Error	93	72182.6	776.16	--	--
Total	97	78758.2	--	--	--

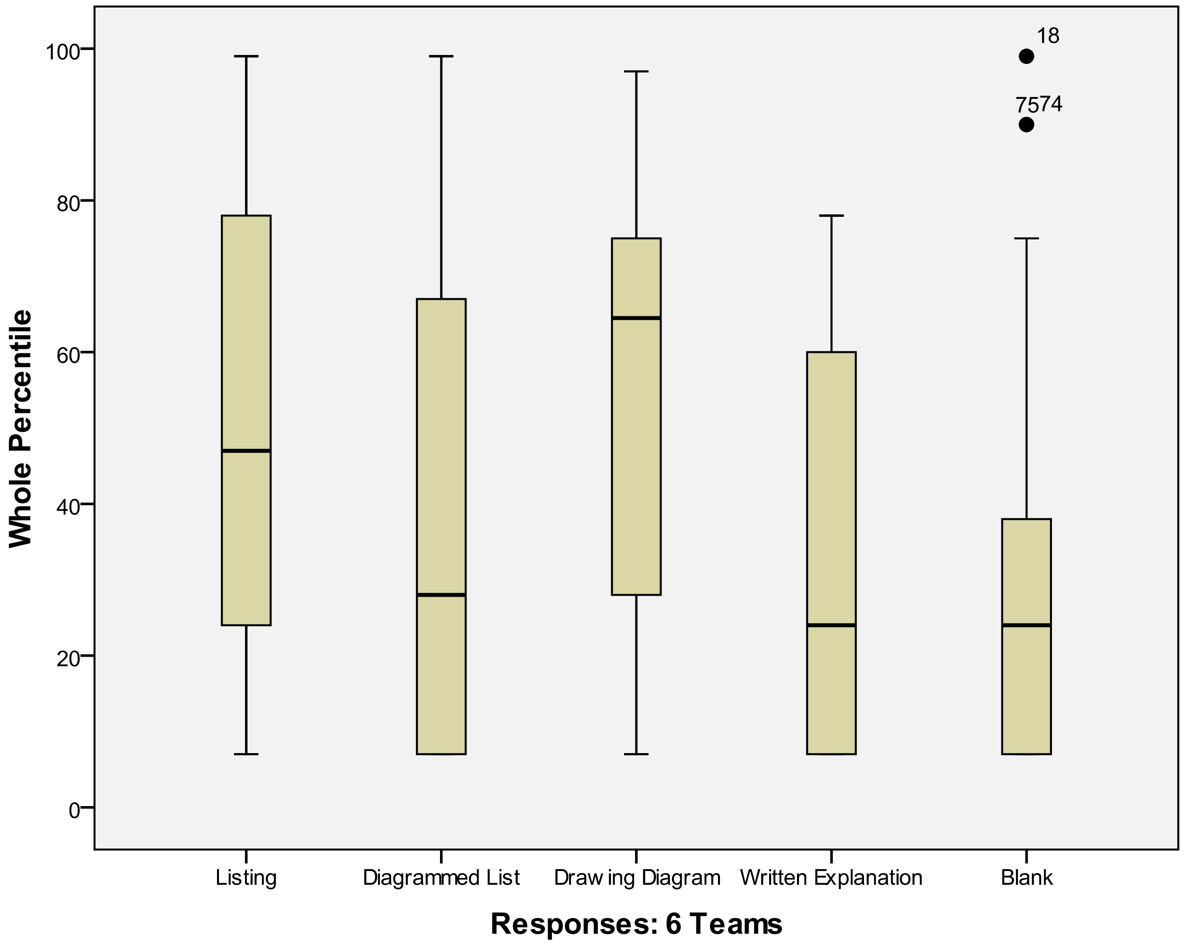

Table 9

Analysis of Variance for Whole Percentile and Responses for 6 Teams

Source	DF	SS	MS	F	P
Groups	4	7590.25	1897.56	2.103	0.0867
Error	93	83930.5	902.48	--	--
Total	97	91520.7	--	--	--

Appendix B

IRB Documents

Assent Form

Study Title: *Relationships between problem solving strategies and brain hemisphericity in High School students.*

Institutional Review Board Approval Number: 2009P200

Hello, my name is Erin Oliver. I am currently a student teacher, from Texas State University, placed at Clear Creek High School. This semester I will be conducting research in your advisory classroom for my Undergraduate Honors Thesis.

The anonymous results of this study will be used to help establish if a relationship exists between the methods students use to solve math problems, and the side of the brain in which they test dominant. The human brain is split down the middle into two sides, each of which specializes in certain tasks. These two sides are connected by the corpus callosum, which runs down the middle and acts as a bridge between the two sides. Some individuals test to be more left brain dominant, right brain dominant or some show more of an integrated dominance. The results of this study could eventually help teachers to improve individual student instruction and raise achievement.

The study will consist of three tasks for you to complete. The first task is simply a demographic questionnaire. The demographics that will be collected are as follows: age, gender, ethnicity, mathematics experience, parents' education, graphing calculator experience and favorite subject. The second task is the Style of Learning and Thinking Questionnaire, developed by Torrance, McCarthy and Smith (1988). This is a 28 question survey which helps determine your brain dominance. Some sample items from the survey are provided below:

Place a check mark in the blank if the statement is true of you. You may check one or both of the statements in a pair or neither – whatever fits you.

_ I tend to solve problems with a playful approach.
_ I tend to solve problems with a serious, business-like approach.

_ I like to express feelings in plain language.
_ I like to express feelings in poetry, song, dance, or art.

The third task that you will complete will be to solve a mathematical word problem. Achieving the correct answer to the problem is not the point of interest. Rather, we are interested in observing the specific methods you choose.

This study is completely voluntary. If at any time you choose not to answer a question, there will be no discrimination towards you in any way. Refusal to participate in this study will not affect your relationship with Texas State University. To maintain anonymity, no names or identifying information will be collected during this study. All data records will be securely held by me, Erin Oliver, through analysis, and will be
discarded after May 15, 2009. Results of the study will be made available upon request. If you have any questions regarding the study, or would like to withdraw yourself from the study please contact me through the contact information provided.

This study will take three small portions of your advisory over three weeks. Willingly accepting the surveys during the next two advisory classes, will affirm your willingness to participate in this study. If you should choose not to participate, you will remain in class to complete other work. Please indicate your name below if you would like to volunteer to be interviewed after the study has taken place. This interview will contribute to the research and would be greatly appreciated. Thank you for your cooperation.

I, ________________________ would like to be contacted to participate in a follow up interview.

Consent Form

Study Title: *Relationships between problem solving strategies and brain hemisphericity in High School students.*

Institutional Review Board Approval Number: 2009P200

Dear Parent/Guardian,

Hello, my name is Erin Oliver. I am currently a student teacher, from Texas State University, placed at Clear Creek High School. This semester I will be conducting research at Clear Creek High School for my Undergraduate Honors Thesis. You can contact me at any time by emailing me at eo1031@txstate.edu or by calling 832-457-1826.

The anonymous results of this study will be used to help establish if a relationship exists between the methods students use to solve math problems, and the side of the brain in which they test dominant. The human brain is split down the middle into two sides, each of which specializes in certain tasks. These two sides are connected by the corpus callosum, which runs down the middle and acts as a bridge between the two sides. Some individuals test to be more left brain dominant, right brain dominant or some show more of an integrated dominance. The results of this study could eventually help teachers to improve individual student instruction and raise achievement.

The study will consist of three tasks for your child to complete. The first task is simply a demographic questionnaire. The demographics that will be collected are as follows: age, gender, ethnicity, mathematics experience, parents' education, graphing calculator experience and favorite subject. The second task is the Style of Learning and Thinking Questionnaire, developed by Torrance, McCarthy and Smith (1988). This is a 28 question survey which helps determine your child's brain dominance. Some sample items from the survey are provided below:

Place a check mark in the blank if the statement is true of you. You may check one or both of the statements in a pair or neither – whatever fits you.

_ I tend to solve problems with a playful approach.
_ I tend to solve problems with a serious, business-like approach.

_ I like to express feelings in plain language.
_ I like to express feelings in poetry, song, dance, or art.

The third task that your child will complete will be to solve a mathematical word problem. Achieving the correct answer to the problem is not the point of interest. Rather, we are interested in observing the specific methods your child chooses.

The selection of the ninth grade campus to complete this study was made for many reasons. The first reason for choosing these students is that not much research has been conducted for students of this age group. Second, most ninth grade students have had the same amount of exposure to mathematical problem solving. The final reason for choosing these students is because of the logistical benefits of the ninth grade center. All ninth graders attend a weekly advisory, which is the location in which this study will take place. This can ensure consistency and randomized selection of the students to participate in the study. The study will only take a small portion of their advisory sessions and no outside work will be requested.

This study is completely voluntary. If at any time your child chooses not to answer a question, there will be no discrimination towards them in any way. Refusal to participate in this study will not affect your child's relationship with Texas State University. To maintain anonymity, no names or identifying information will be collected during this study. All data records will be securely held by me, Erin Oliver, through analysis, and will be discarded after May 15, 2009. Results of the study will be made available upon request. If you have any questions regarding the study, or would like to withdraw your child from the study please contact me through the contact information provided. If you have any other questions about this research study please contact Dr. Jon Lasser or Ms. Becky Northcut, whose contact information is provided below.

I thank you for your consideration and for your child's participation in this study. It is my hope that the results of this study will lead to important implications for the field of mathematics education.

Sincerely,
Miss Erin Oliver
Eo1031@txstate.edu
832-457-1826

Dr. Jon Lasser
lasser@txstate.edu
512-245-3413

Ms. Becky Northcut
512-245-2102

TEXAS STATE UNIVERSITY
SAN MARCOS
The rising STAR of Texas

Institutional Review Board Application

Certificate of Approval

Applicant: Erin Oliver

Application Number : 2009P200

Project Title: Relationship between problem solving strategies and brain hemisphericity in High School mathematics students.

Date of Approval: 03/04/09

Expiration Date: 03/04/10

Assistant Vice President for Research and Federal Relations

Chair, Institutional Review Board

Appendix C

Instruments

DEMOGRAPHIC QUESTIONNAIRE

1. Age (circle one): 11or younger 12 13 14 15 16 17 or older

2. Gender (circle one): Male Female

3. Ethnicity (circle one):

Caucasian Hispanic African American Asian Other

4. Current Mathematics Class (circle one):

8th Grade Math	Geometry	Algebra II (Enriched)
8th Grade Math (PreAP/GT)	Geometry (PreAP/GT)	Algebra II (PreAp/GT)
Algebra I	Math Models	Precalculus
Algebra I (PreAP/GT)	Algebra II	Precalculus (PreAP/GT)

Other (Please List):

5. Please <u>circle all</u> of your Previous Math Classes:

8th Grade Math	Geometry	Algebra II (Enriched)
8th Grade Math (PreAP/GT)	Geometry (PreAP/GT)	Algebra II (PreAp/GT)
Algebra I	Math Models	Precalculus
Algebra I (PreAP/GT)	Algebra II	Precalculus (PreAP/GT)

Other (Please List):

6. Are you classified as an English Language Learner (circle one)?

Yes No

7. Are you or have you ever been classified as a gifted learner (circle one)?

Yes No

8. Highest Degree of Parents Education (circle one):

Both graduated from College One graduated from College

Neither graduated from College

Both graduated High School One graduated High School

Neither graduated High School

9. How many years including this year have you used a graphing calculator in the classroom (circle one)?

0 1 2 3 4 or more

10. How do you feel about mathematics (circle one)?

I hate it! I dislike it. It is alright. I like it. I love it!

11. Please list any extracurricular math experience (clubs, math camps, competitions):

12. Please list your favorite subject and why:

Mathematics Problem

Instructions:

Please show how you would answer each of the following problems by using the first method that comes to you. It is very important to show (on this paper) how you are thinking of the problem and your thought process. Having the correct answer is not the focus of this exercise. We want to see the way you think about the problem.

Problem:

A High School is hosting a round robin soccer tournament, in which each team must play every other team once. For each of the following numbers of teams, please indicate how many total games would be played. I should be able to look at your work, and determine the number of games for each situation.

2 Teams

3 Teams

4 Teams

5 Teams

6 Teams

Have you solved a similar problem before? Yes No

Style of Learning and Thinking (SOLAT®)

Youth Form

By: Torrance, McCarthy, & Kolesinski

Name: ______________________________ Age: ________ Sex: ______

School: ____________________________ Grade: ______ Date: __________

Directions: Place a check mark in the blank if the statement is true of you. You may check one or both of the statements in a pair or neither—whatever fits you.

1. ______ I like to read explanations of what I am supposed to do.
   ______ I like to have things explained by showing them to me.
2. ______ I am good at body language.
   ______ I am not good at body language; I prefer to say what I think and depend on what people say.
3. ______ I enjoy classes where I listen to the teacher.
   ______ I enjoy classes in which I move around and try things.
4. ______ I tend to solve problems with a playful approach.
   ______ I tend to solve problems with a serious, business-like approach.
5. ______ I use only the proper materials to get a job done.
   ______ I will use whatever is available to get a job done.
6. ______ I like class or work to be planned so I know exactly what to do.
   ______ I like class or work to be open-ended with opportunities for change as I go along.
7. ______ I like to play hunches or guess.
   ______ I would rather not guess or play hunches.
8. ______ I like to express feelings in plain language.
   ______ I like to express feelings in poetry, song, dance, or art.
9. ______ I like to learn about things we are sure of.
   ______ I like to learn about hidden possibilities.
10. ______ I like to take ideas apart and think about them separately.
    ______ I like to put a lot of ideas together.
11. ______ I am good at using logic in solving problems.
    ______ I am good at using feelings and intuitions in solving problems.
12. ______ I like to see and imagine things when I solve problems.
    ______ I like to analyze problems by reading and listening to teachers who know.
13. ______ I learn easily from teachers who explain with words.
    ______ I learn easily from teachers who explain by movement and action.

14. ______ When I remember or think about things, I do well with words.
______ When I remember or think about things, I do well with pictures and images.

15. ______ I like to see something that is finished or completed.
______ I like to organize and complete something that is unfinished.

16. ______ I am intellectual.
______ I am intuitive.

17. ______ I am good at learning details and specific facts.
______ I am good at learning from a general overview, the whole picture.

18. ______ I learn and remember those things specifically studied.
______ I learn and remember details and facts I pick up from things happening around me.

19. ______ I like to read stories about things that really happen.
______ I like to read stories about made up things.

20. ______ It is fun to plan what I am going to do.
______ It is fun to dream.

21. ______ I like listening to music while reading or studying.
______ I like total quiet when reading or studying.

22. ______ I enjoy copying and filling in details.
______ I enjoy drawing my own images and ideas.

23. ______ It is exciting to invent something.
______ It is exciting to improve something.

24. ______ I learn well by exploring.
______ I learn well by examining.

25. ______ I like ideas presented in order.
______ I like ideas presented with relationships.

26. ______ I am good at remembering verbal materials.
______ I am good at remembering sounds and tones.

27. ______ I am absentminded often.
______ I am almost never absentminded.

28. ______ I enjoy summarizing.
______ I enjoy outlining.

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Cat. #SC-142

1.	L	R
2.	R	L
3.	L	R
4.	R	L
5.	L	R
6.	L	R
7.	R	L
8.	L	R
9.	L	R
10.	L	R
11.	L	R
12.	R	L
13.	L	R
14.	L	R
15.	L	R
16.	L	R
17.	L	R
18.	L	R
19.	L	R
20.	L	R
21.	R	L
22.	L	R
23.	R	L
24.	R	L
25.	L	R
26.	L	R
27.	R	L
28	R	L

To score and profile your SOLAT Test, first count the number of times you checked both boxes for an item, and write that number in box "W".

Next, count the number of times you checked only "L" for an item, and write that number in box "L".

Then count the number of times you checked only "R" for an item, and write that number in box "R".

W ☐ — the number of times you checked "L" & "R"

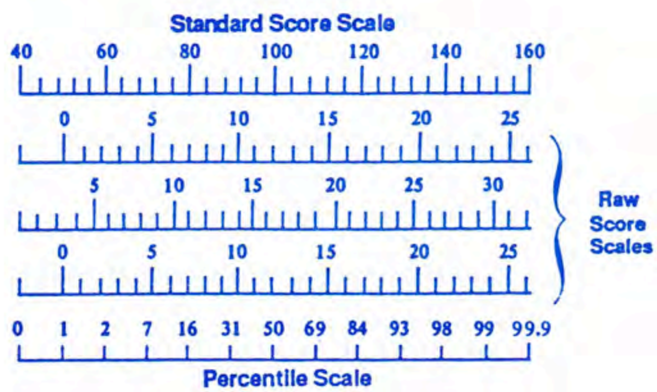
L ☐ — the number of times you checked "L"

R ☐ — the number of times you checked "R"

You can profile your results on the chart below. Enter the "raw score" totals from the box above onto the lines provided below (left, right, whole); then, mark in these numbers at the appropriate point on the three raw score scales below that.

Once you have indicated the raw scores, draw a line up and down from the points you marked on the three raw score scales, through the scales above and below the raw score scales. You can now see your "standard score" and the "percentile" you scored in. Enter these numbers next to where you first entered your raw scores, on the lines provided above the scales.

	Raw Score	Standard Score	Percentile
W's (Whole)	_______	_______	_______
L's (Left)	_______	_______	_______
R's (Right)	_______	_______	_______



Appendix D

Data Collection Instructions

DATA COLLECTION INSTRUCTIONS

Summary:

This study will take place over two advisory sessions. Each data collection session should only take about 15-20 minutes. Because this study is being used for research purposes, the results must remain anonymous. For this reason you will hold on to the ROLL SHEET which will contain each student's ID Number and then destroy it by shredding it after the second day of testing. Also, Consent/Assent Forms must be passed out at the beginning of every day of testing. This is a rule from the Texas State University Institutional Review Board. I will provide all needed forms for you.

Day One (April 2, 2009):

- Pass out the Assent and Consent Forms before doing anything. Instruct the students to read the Assent Form and allow time for them to do so. Also, tell them to take the Consent Form home to their parents/guardians.

On this day of testing, students will be filling out a demographic questionnaire and answering a mathematics problem. If a student is absent please write ABSENT at the top of the paper and place it in the folder. A power point presentation will be provided for your students to follow. Leave the slide that says Demographic Questionnaire up and have them fill out the questionnaire. Then move to the slide that says Mathematical Problem and have them work it following the instructions. Please read the power point word for word to the students. Offer clarification if they need it, but do not suggest anything as to the methods to solve the problems. Some ideas to emphasize are the following:

- Please use the first method that comes to your mind.
- You must show you work and the methods you used to arrive at your answer for each problem.
- Achieving the correct answer is not the point of interest.

Once they have filled out the demographic questionnaire and answered the problem completely, go to the final slide. The students will need to bring both documents up to you and staple them together. Then they will write their name beside their ID Number on the ROLL SHEET. After they turn it in please make sure that they do not have any identifying information written on the documents, and make sure they have followed instructions as far as circling answers. Some questions on the questionnaire require more than one answer and some require a single answer. Then check to make sure they completed the math problem. No blank forms should be accepted. Also, please double check that they wrote their name by the appropriate ID Number on the ROLL SHEET. This can be checked by looking at the top of each questionnaire to ensure that the ID Number matches with the students name on the ROLL SHEET. Place all finished questionnaires with the math problem stapled to the back in the folder and I will be by to pick them up either at the end of advisory or at the beginning of 7th period.

Day Two (April 9, 2009):

- Pass out the Assent and Consent Forms before doing anything. Instruct the students to read the Assent Form and allow time for them to do so. Also, tell them to take the Consent Form home to their parents/guardians.

On the second day, pass the SOLAT forms out to the students one-by-one according to the numbers on the ROLL SHEET. Read the instructions and power point to the students and make sure that they have a good understanding of how to respond on the form. Make sure the students complete the questionnaire before they turn it in. It is okay if some are left blank, but most should be answered. Once all surveys have been returned please destroy the roll sheet by shredding it completely. I cannot see the names of the students accompanied with the ID Numbers. This would break the anonymity of the study. Place all finished questionnaires in the folder and I will be by to pick them up either at the end of advisory or at the beginning of 7th period.

Research Study Instructions

Consent/Assent Forms

- Pass out Consent and Assent Forms to all students in advisory classroom.
- Students, PLEASE READ ASSENT FORMS.
- Students, PLEASE TAKE HOME the Consent Forms to your parents/guardians.

Demographic Questionnaire

- Once you receive the Demographic Questionnaire STOP!!!!
- <u>DO NOT</u> WRITE YOU NAME ON THE QUESTIONNAIRE!!!!
- Completely fill out all of the questions.
- Make sure you follow the instructions for each question.

Mathematics Problem

- Read the instruction on the problem handout.
- DO NOT WRITE YOUR NAME!!!!!
- NO CALCULATORS!!!!
- Make sure you <u>show what you are thinking</u>.
- I should be able to look at each portion of the problem and determine the number of games that will be played.
- Answer each of the questions to the best of your ability.
- Achieving the correct answer is not the point of interest.

When you are finished....

- The number at the top of the demographic questionnaire will be your ID number.
- STAPLE the mathematics problem to the back of your demographic questionnaire.
- Write you name beside your ID number on the <u>roll sheet</u> before turning in your questionnaire.
- Give your <u>filled out and stapled</u> Demographic Questionnaire and Mathematics Problem to your advisory teacher.

Style of Learning and Thinking Questionnaire

Style of Learning and Thinking

- DO NOT WRITE YOUR NAME!!!
- Only answer questions 1-28, DO NOT WRITE ON ANYTHING ELSE!!!!
- Please write in pen.
- Do not open the tests. Answer the front page and then flip it over to finish.

How to Answer Questions

- Check the first statement if it describes you.
- Check the second statement if it describes you.
- Check both statements if you are good at both or enjoy both, and if you do not have a strong preference for either.
- Leave both blank if you are not good at either or if you enjoy neither.

Anonymity

- All results of these surveys are completely anonymous.
- The surveys you completed are only connected by the ID Number to allow for comparison later.
- The ROLL SHEET with your names and ID Numbers will be destroyed by your teacher, and has remained unseen to the researcher.

Thank You

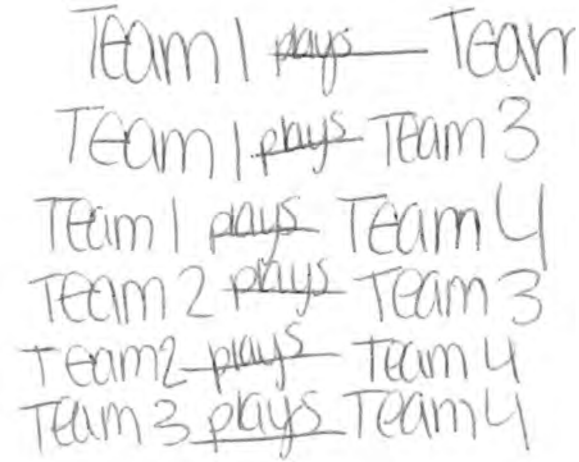
- Thank you all for completing these surveys.
- Your participation is greatly appreciated.
- Results will be made available upon the completion of this project (May 15).
- Good luck with the remainder of the school year!!!!!

Appendix E

Raw Data

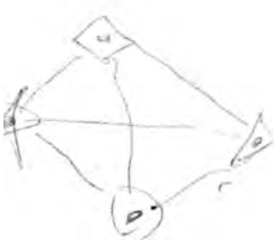
Student Responses to Mathematics Problem

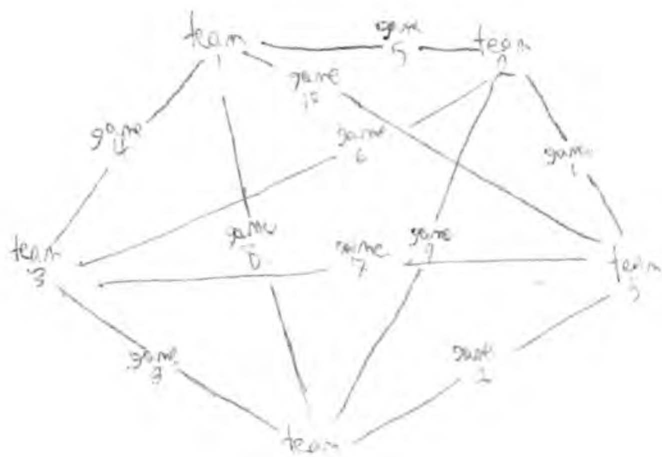
Listing



Diagrammed Listing

Diagram





Verbal Explanation

Well see, if there is two teams there's only gonna be 1 game. A team can't play against itself (duh), so it's always one less than the # of teams

ach team is playing once.

re are 6 teams, so 3 games would be

layed.

Blank / I Don't Know

IDK

Tables Represent Demographic Data, Mathematical Problem Responses and SOLAT Scores:

Student ID Number	Age	Gender	Ethnicity	Math Class	ELL	GT	Parent EDU	Calc Exp	Rate Math	Extra Math	Fav Sub
1	15	1	2	3	1	0	6	1	3	0	1
2	16	1	4	3	1	0	1	1	1	0	2
3	14	2	1	4	0	1	2	2	4	0	1
4	15	2	1	3	0	0	2	1	3	0	3
5	14	1	1	4	0	1	1	1	1	0	4
6	15	1	2	3	0	1	2	2	4	1	1
7	14	2	1	3	0	0	4	1	1	0	5
8	15	1	3	3	1	0	1	1	3	0	6
9	14	1	1	3	0	0	2	1	4	0	1
10	15	2	1	3	0	1	3	2	2	0	3
11	15	1	1	3	0	0	4	2	3	0	4
12	15	1	1	3	0	0	1	2	4	0	7
13	14	1	2	3	0	0	4	1	3	0	0
14	14	1	5	3	0	1	2	2	1	0	8
16	14	2	2	3	0	0	5	1	1	0	4
17	15	2	3	3	1	1	3	1	1	0	6
18	15	1	1	3	0	0	1	1	3	0	5
19	14	2	1	3	0	0	1	1	3	0	3
20	16	1	5	3	0	0	4	1	2	0	9
21	14	1	1	3	0	1	6	1	1	0	15
22	15	1	1	3	0	0	4	1	3	0	15
23	14	1	2	3	1	0	6	1	1	2	4
26	15	1	2	6	0	0	1	2	1	0	4
27	15	2	4	4	1	0	1	4	4	0	8
29	15	1	1	4	0	0	1	2	3	0	9
30	16	1	3	3	0	0	2	4	5	0	1
31	15	1	1	3	0	0	4	1	5	0	1
32	14	2	1	10	0	1	1	3	3	0	8
33	15	2	1	6	0	0	1	2	4	0	3
34	15	2	1	4	0	0	1	1	3	0	8
37	15	1	2	3	0	0	3	1	4	0	1
38	15	2	1	4	0	0	1	2	4	0	1
41	14	2	5	5	0	1	2	2	4	0	1
42	15	1	3	3	0	0	4	2	3	0	6
43	15	2	2	3	0	0	1	1	3	0	11
44	15	1	1	4	0	0	1	1	3	0	6
46	15	1	1	10	0	1	1	2	5	3	1
47	15	2	3	3	0	1	2	1	4	0	12

48	15	2	1	4	0	1	3	1	3	0	1
49	15	1	1	3	0	1	2	2	3	0	3
51	15	1	1	3	0	1	1	1	3	0	11
52	14	2	5	4	1	1	2	1	3	0	6
53	14	1	1	4	0	0	1	1	4	0	6
54	15	1	4	3	1	0	1	1	3	0	3
55	14	2	2	6	1	1	1	2	4	0	1
56	15	1	2	4	0	0	1	1	3	0	4
57	15	1	5	6	1	1	1	2	3	4	6
58	14	2	1	10	0	1	1	3	4	0	1
59	15	1	1	3	0	0	1	1	1	0	15
60	15	1	2	6	0	1	4	2	4	0	3
61	14	2	1	4	0	0	2	2	1	0	15
62	15	2	2	3	0	0	1	1	1	0	3
63	15	1	1	3	1	0	1	1	2	0	13
64	15	2	1	3	0	0	1	2	5	0	1
65	14	2	1	5	0	1	1	2	4	0	8
66	15	2	2	6	0	1	1	2	3	0	8
67	14	1	2	3	1	0	6	1	1	0	4
68	15	2	1	3	1	1	3	2	5	0	1
69	15	1	1	3	0	1	4	1	1	0	9
70	14	2	1	4	0	0	4	1	3	0	6
71	14	2	1	4	0	0	1	2	2	0	6
72	15	1	1	3	0	0	2	2	3	0	3
73	14	2	2	4	0	1	1	2	5	4	1
74	14	1	2	6	0	1	2	2	5	0	1
75	15	2	2	3	1	0	0	2	3	0	9
76	16	1	4	3	0	0	0	5	0	0	0
77	14	1	2	6	0	1	4	2	3	0	1
78	15	1	1	3	0	0	1	1	1	0	3
80	15	2	1	4	0	0	1	1	3	0	8
81	15	1	5	3	1	0	1	2	3	0	6
85	15	2	2	4	0	1	1	2	4	0	8
86	15	2	1	4	0	1	1	1	5	0	1
87	14	2	1	3	0	0	1	1	2	5	14
88	15	1	2	3	0	1	2	1	4	0	12
89	15	2	1	3	0	0	1	2	5	0	1
90	14	2	1	3	0	1	1	1	3	0	6
96	14	1	1	3	0	0	4	2	3	0	7
97	15	1	2	3	1	0	2	1	4	0	7

98	15	2	1	3	0	1	1	0	3	0	11
99	14	2	1	4	0	0	2	1	2	0	12
100	15	2	3	3	0	0	2	4	2	0	9
101	15	2	1	3	0	0	3	1	3	0	6
102	15	2	1	3	0	0	5	1	3	0	6
103	14	2	1	3	0	0	2	1	2	0	0
104	15	2	2	3	1	0	5	1	1	0	14
105	15	2	2	3	1	0	3	1	3	0	6
106	14	2	2	3	1	0	1	1	3	0	3
107	15	2	5	6	0	1	1	2	3	0	3
108	15	1	1	3	0	0	1	2	1	0	3
110	14	1	1	3	0	1	2	0	3	0	11
111	15	2	1	3	0	0	4	1	4	0	1
112	15	1	2	4	1	0	2	1	3	0	9
113	15	2	1	3	0	0	5	1	1	0	14
114	16	2	5	3	1	1	4	1	1	0	3
115	15	2	3	3	1	1	2	1	1	0	14
116	14	1	3	3	1	0	1	1	1	0	14
117	15	2	2	3	0	0	5	0	1	0	6
118	16	1	1	3	0	0	4	1	4	0	1

Student ID Number	PAP Math 8	ALG1	PAP ALG1	Geom	PAP Geom	Mmod	ALG2	EN ALG2	PAP ALG2	PreCal	PAP PreCal
1	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0

22	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0
26	1	0	1	0	0	0	0	0	0	0	0
27	1	0	0	0	0	0	0	0	0	0	0
29	1	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0
32	1	0	1	0	1	0	0	0	0	0	0
33	1	0	1	0	0	0	0	0	0	0	0
34	1	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0
38	1	0	0	0	0	0	0	0	0	0	0
41	1	0	1	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0
44	1	0	0	0	0	0	0	0	0	0	0
46	1	0	1	0	1	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0
48	1	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0
52	1	0	0	0	0	0	0	0	0	0	0
53	1	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0
55	1	0	1	0	0	0	0	0	0	0	0
56	1	0	0	0	0	0	0	0	0	0	0
57	1	0	1	0	0	0	0	0	0	0	0
58	1	0	1	0	1	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0
60	1	0	1	0	0	0	0	0	0	0	0
61	1	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0
65	0	1	0	0	0	0	0	0	0	0	0
66	1	0	1	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0
68	1	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0
70	1	0	0	0	0	0	0	0	0	0	0
71	1	0	0	0	0	0	0	0	0	0	0
72	1	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0
74	1	0	1	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0

77	1	0	1	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0
80	1	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0
85	1	0	0	0	0	0	0	0	0	0	0
86	1	0	0	0	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0
90	1	0	0	0	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0	0	0
97	0	0	0	0	0	0	0	0	0	0	0
98	1	0	0	0	0	0	0	0	0	0	0
99	1	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0
101	1	0	0	0	0	0	0	0	0	0	0
102	0	0	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0	0	0	0	0
104	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0
107	1	0	1	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0
111	0	0	0	0	0	0	0	0	0	0	0
112	1	0	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0

Student ID Number	2-teams	3-teams	4-teams	5-teams	6-teams	Experience
1	6	6	8	6	8	2
2	2	2	2	2	8	0
3	1	1	1	3	3	1
4	4	7	7	2	2	1
5	6	6	4	4	6	0
6	1	3	9	9	9	1
7	3	2	2	2	2	1
8	2	2	6	2	6	0
9	6	5	5	5	5	0
10	4	4	4	4	4	1
11	1	1	1	1	1	0
12	4	4	4	4	4	1
13	4	4	6	6	6	1
14	1	1	1	1	1	2
16	5	9	8	8	8	0
17	9	8	8	8	8	2
18	3	3	3	3	3	0
19	5	8	8	8	8	1
20	6	9	9	8	8	0
21	6	1	1	1	1	1
22	8	8	8	8	8	0
23	6	2	2	2	6	1
26	6	6	5	6	6	1
27	6	1	1	1	1	1
29	6	7	7	7	7	1
30	8	8	8	8	8	0
31	2	2	2	2	6	0
32	3	3	2	2	2	1
33	3	1	1	1	1	1
34	1	1	1	1	1	1
37	1	1	1	1	1	0
38	6	2	2	2	2	1
41	6	1	1	1	1	0
42	6	6	8	8	8	0
43	7	3	3	3	3	1
44	6	1	1	1	1	0
46	2	2	2	2	2	1
47	6	3	3	3	3	1

48	5	3	3	3	3	0
49	1	1	1	1	1	0
51	6	1	1	1	1	0
52	6	6	6	6	6	0
53	6	6	6	7	7	1
54	4	4	4	8	8	2
55	1	1	1	1	1	0
56	4	4	4	4	4	1
57	6	1	1	1	7	1
58	2	2	2	2	2	1
59	6	2	2	2	2	0
60	6	4	4	1	1	0
61	6	2	2	2	4	0
62	1	1	1	1	1	1
63	2	2	2	2	5	1
64	1	1	1	1	1	1
65	1	1	1	1	1	1
66	4	4	4	8	8	2
67	7	2	2	2	2	0
68	1	1	1	8	8	2
69	8	3	8	8	8	0
70	2	2	2	2	2	0
71	7	7	7	7	7	1
72	3	3	4	4	4	0
73	6	7	7	7	7	0
74	6	6	6	6	6	1
75	2	2	2	2	2	0
76	6	2	2	2	2	0
77	2	2	2	2	2	1
78	6	4	4	4	4	0
80	2	2	2	2	2	0
81	2	2	2	2	2	1
85	2	2	1	1	1	1
86	4	4	4	4	4	1
87	6	6	6	6	6	1
88	9	8	8	8	8	1
89	9	8	8	8	8	0
90	6	6	6	6	6	0
96	6	6	2	8	8	2
97	9	8	8	8	8	0
98	9	8	8	8	8	1

99	9	8	8	8	8	0
100	1	1	6	8	8	2
101	4	4	4	4	4	0
102	2	2	2	2	2	1
103	9	8	8	8	8	1
104	6	6	6	8	8	2
105	2	2	2	2	4	1
106	3	1	1	1	1	0
107	2	2	2	8	8	2
108	2	2	2	2	2	1
110	7	2	2	7	7	1
111	7	7	7	7	7	0
112	7	7	7	7	7	1
113	2	2	2	8	8	2
114	8	8	8	8	8	2
115	8	8	8	8	8	2
116	6	2	2	2	2	0
117	9	8	8	8	8	2
118	2	9	8	8	8	2

Student ID Number	Left Raw	Left Standard	Left Percentile	Right Raw	Right Standard	Right Percentile	Whole Raw	Whole Standard	Whole Percentile	Blank
1	11	112	78	9	96	47	8	105	67	0
2	9	103	62	15	118	84	0	73	7	4
3	4	82	21	15	118	84	9	109	72	0
4	15	129	95	6	84	30	4	89	38	3
5	5	86	28	12	107	65	11	116	78	0
6	7	95	49	21	143	99	0	73	7	0
7	1	70	7	20	142	99	6	97	53	1
8	8	99	54	9	96	47	8	105	67	3
9	4	82	21	7	88	37	0	73	7	17
10	5	86	28	17	126	95	6	97	53	0
11	9	103	62	17	126	95	2	81	24	0
12	8	99	54	15	118	84	5	93	47	0
13	6	91	34	16	122	90	6	97	53	0
14	3	78	18	6	84	30	19	148	99	0
16	1	70	7	8	92	42	2	81	24	17
17	13	120	88	15	118	84	0	73	7	0
18	7	95	49	6	84	30	8	105	67	7
19	5	86	28	5	80	20	17	144	99	1
20	2	74	15	26	148	99	0	73	7	0

21	4	82	21	24	146	99	0	73	7	0
22	5	86	28	23	145	99	0	73	7	0
23	13	120	88	10	99	53	0	73	7	5
26	20	151	99	5	80	20	3	85	28	0
27	4	82	21	8	92	42	16	140	97	0
29	7	95	49	15	118	84	6	97	53	0
30	18	149	99	10	99	53	0	73	7	0
31	12	116	82	16	122	90	0	73	7	0
32	4	82	21	14	115	79	10	113	75	0
33	17	141	97	11	103	57	0	73	7	0
34	13	120	88	10	99	53	4	89	38	1
37	6	91	34	14	115	79	5	93	47	3
38	12	116	82	4	76	15	8	105	67	4
41	10	107	68	12	107	65	6	97	53	0
42	8	99	54	2	69	7	4	89	38	14
43	3	78	18	14	115	79	11	116	78	0
44	5	86	28	10	99	53	10	113	75	3
46	1	70	7	3	72	9	24	158	99	0
47	8	99	54	9	96	47	10	113	75	1
48	4	82	21	12	107	65	11	116	78	1
49	3	78	18	8	92	42	16	140	97	1

51	4	82	21	8	92	42	12	120	83	4
52	8	99	54	20	142	99	0	73	7	0
53	11	112	78	9	96	47	4	89	38	4
54	12	116	82	16	122	90	0	73	7	0
55	8	99	54	15	118	84	0	73	7	5
56	7	95	49	13	111	70	7	101	62	1
57	11	112	78	12	107	65	3	85	28	2
58	6	91	34	19	141	99	0	73	7	3
59	15	129	95	11	103	57	0	73	7	2
60	6	91	34	9	96	47	13	124	90	0
61	14	124	92	13	111	70	1	77	20	0
62	4	82	21	24	146	99	0	73	7	0
63	2	74	15	14	115	79	10	113	75	2
64	9	103	62	16	122	90	3	85	28	0
65	3	78	18	14	115	79	11	116	78	0
66	1	70	7	19	141	99	8	105	67	0
67	6	91	34	14	115	79	1	77	20	7
68	14	124	92	10	99	53	3	85	28	1
69	6	91	34	20	142	99	2	81	24	0
70	12	116	82	16	122	90	0	73	7	0
71	7	95	49	21	143	99	0	73	7	0

72	16	137	96	8	92	42	3	85	28	1
73	20	151	99	7	88	37	0	73	7	1
74	12	116	82	10	99	53	6	97	53	0
75	8	99	54	10	99	53	3	85	28	7
76	10	107	68	15	118	84	2	81	24	1
77	6	91	34	12	107	65	10	113	75	0
78	3	78	18	19	141	99	2	81	24	4
80	7	95	49	17	126	95	3	85	28	1
81	8	99	54	19	141	99	0	73	7	1
85	0	65	5	21	143	99	7	101	62	0
86	4	82	21	24	146	99	0	73	7	0
87	16	137	96	11	103	57	1	77	20	0
88	6	91	34	9	96	47	13	124	90	0
89	11	112	78	4	76	15	13	124	90	0
90	10	107	68	18	138	96	0	73	7	0
96	13	120	88	14	115	79	1	77	20	0
97	11	112	78	7	88	37	10	113	75	0
98	5	86	28	21	143	99	2	81	24	0
99	4	82	21	24	146	99	0	73	7	0
100	8	99	54	19	141	99	0	73	7	1
101	0	65	5	19	141	99	8	105	67	1

102	10	107	68	18	138	96	0	73	7	0
103	8	99	54	17	126	95	3	85	28	0
104	8	99	54	19	141	99	1	77	20	0
105	5	86	28	7	88	37	16	140	97	0
106	7	95	49	15	118	84	6	97	53	0
107	2	74	15	22	144	99	3	85	28	1
108	12	116	82	4	76	15	11	116	78	1
110	5	86	28	6	84	30	17	144	99	0
111	13	120	88	11	103	57	4	89	38	0
112	4	82	21	19	141	99	5	93	47	0
113	7	95	49	13	111	70	3	85	28	5
114	11	112	78	17	126	95	0	73	7	0
115	8	99	54	18	138	96	0	73	7	2
116	15	129	95	9	96	47	4	89	38	0
117	9	103	62	16	122	90	3	85	28	0
118	7	95	49	5	80	20	8	105	67	8