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EXPLORING STUDENT PERSEVERANCE IN PROBLEM SOLVING

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Masters of Natural Sciences

in

The Interdepartmental Program in Natural Sciences

by
Angelique Renee Treadway Duncker
B.S., University of Louisiana, Lafayette, 2008
August 2013

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ABSTRACT

Many high school Geometry students lack the perseverance required to complete complex and time-consuming problems. This project tests the hypothesis that if students were provided with a means of organizing their problem solving work they will be less apt to quit when faced with complex and time-consuming mathematical problems. This study involved students enrolled in 10^{th} grade Geometry and 10^{th} grade Honors Geometry in two similar high schools. After trying unsuccessfully to implement methods adapted from an engineering workshop, I designed a graphic organizer that was simple to use and acceptable to the students. Ultimately, I did not detect a direct effect on perseverance, but the graphic organizer appeared to increase student communications about problem solving and aided the teacher in quickly diagnosing student problem-solving progress. Thus, it did help to create classroom conditions conducive to student engagement.

CHAPTER 1: INTRODUCTION

Incorporated within the Common Core State Standards, the first of the so-called standards of practice is to, "Make sense of problems and persevere in solving them" (National Governors Association Center for Best Practices, 2010b). The Common Core State Standards continue to describe exactly how a mathematically proficient student should demonstrate their knowledge and perseverance:

> Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than just jumping into the solution attempt. (National Governors Association Center for Best Practices, 2010b)

In general, high school students lack the resilience, structure, and perseverance required to solve complex, multi-step, mathematical problems. Is it possible to address this problem by implementing engineering practices and problem solving methods in the high school geometry classroom? Is there any way to inspire students to persist beyond twelve minutes and further than two steps into a problem before giving up?

In the age of teacher accountability and transition from state-defined learning goals to the Common Core State Standards, a teacher must be more than hopeful of their student's success. A teacher must be effective in creating the desire, will, and ability to solve difficult, multi-step problems consistently and accurately within their students while overcoming the misconceptions, fears, and socioeconomic factors that are the "package deal" with any student body. But, how does a teacher overcome the negative emotions, misconceptions, stereotyping, and apathetic attitudes of their students to create proficient, resilient, and consistently accurate problem solvers?

According to the research on building problem solving skills, the most successful methods are those in which the teacher scaffolds information for the students by providing a predictable inquiry framework through which students fulfill expectations regarding sense-making, personal ownership, self-monitoring, and justification for their thoughts and solutions (Clark, 2008; Goos, 2004). Scaffolding is an educational technique which encourages the teacher to act in the role as an informal tutor to get the student "on their feet" and then gradually withdraws tutorial supports (Kalina & Powell, 2010). This gradual withdrawal of support allows the student to build confidence by experiencing success in their problem solving attempts and in their independent problem solving abilities, while building the cognitive organizational skills necessary to recall the information learned, therefore allowing the student to apply the information or "tools" necessary to successfully solve the problem at hand (Van De Pol, Volman, & Beishuizen, 2010). Students who possess the skills to organize their subject knowledge were shown to be consistently better problem solvers and could recall a substantial amount of their available knowledge when prompted to do so (Lawson & Chinnappan, 2000).

In the summer of 2010, I attended the Louisiana Research Experience for Teachers workshop sponsored by the Gordon A. Cain Center for STEM Literacy. Within this workshop, I was taught the so-called, "Engineering Method of Problem Solving" as a means of scaffolding complex problems. We were given several problem-based projects to complete over the 4-day course of the workshop. I utilized the method to aid me in the organization of my problem solving, and I felt my students would find it helpful as well.

Research has shown enacting the engineering problem solving method in a classroom of inquiry will afford learners tangible evidence of their success create a sense of accomplishment, and this positive reinforcement will lead to increased perseverance through difficult problems. I

hoped that by crafting problem solving routines in which students utilized the Engineering Method, I could change the problem solving experience in a way that would increase students' willingness to persevere through difficult, challenging, or unfamiliar mathematical territory. The engineering method as it applies to mathematical problem solving is a fluid, multi-step approach which, when practiced consistently, becomes imbedded as a schema to the cognitive processes of the student. Students who are able to develop and/or adopt personal problem solving models become more sophisticated in their solving methods as a whole and demonstrate the perseverance necessary in which to complete the problem solving process (Hamilton, Lesh, Lester, & Yoon, 2007).

As any teacher knows, things do not always go as expected. My students were not receptive to the Engineering Method that I found to be so helpful in my own work. The precise reason for this will be described in upcoming chapters. Because of this, I went back to the research and searched for an effective scaffolding method that would be more acceptable to the students. This led to a simple device called the graphic organizer. The graphic organizer was a success with the students in particular ways, and I discovered that the graphic organizer afforded many mutual benefits for the both the teacher and the students.

The focus of this thesis is not to suggest a panacea for the difficulties experienced by students during problem solving, but just to find some ways of providing them with the structure required for their efforts to result in a mathematically successful solution. The ensuing chapter, contains a literature review of the research in three parts. The first part discusses the issue of resilience and perseverance. The second part is a review of the research on scaffolding. The remainder of the literature review focuses on the Engineering Problem Solving Method a proposed implementation of scaffolding. Chapter 3 describes the settings for this research and

the preliminary work that went into the development of our primary artifact, known as the graphic organizer. Within Chapter 4, the research process is described along with an overview of the classroom assignments used in this study. Chapter 5 presents the data collected for this study; including usage data, student work, test data, survey data, and observations made during the course of this study. In Chapter 6, I discuss the data. My conclusions and directions for future research are detailed in Chapter 7.

CHAPTER 2: LITERATURE REVIEW

The literature review is presented in three parts. The first section is a discussion about resilience and perseverance. The second discusses the educational practice of scaffolding. The third discusses the Engineering Method of problem solving and its rationale.

2.1 Resilience and Perseverance

Personal observations as a classroom teacher of high school mathematics and within the research, this problem has been well-documented by educators and researchers alike, as evidenced in Sternberg's collection of journal articles, Optimizing Student Success in School with the Other Three R's (Sternberg, 2006). Sternberg and the other contributors maintain that the compulsory "reading, writing, and arithmetic" skills currently taught in school are simply for naught without the "Other Three R's"; the skills to develop reasoning, resilience, and responsibility within students. The student's ability to reason through the problem, the student's resilience to persist towards a satisfactory solution despite mathematical challenge, and the student's sense of personal and academic responsibility to complete the problem successfully weave a complex interplay of emotions, cognitive processes, and physical responses which are observed in the class room on a daily basis. In addition to the complex amalgamation of cognitive and emotional processes taking place inside each student, every individual is influenced by previous experiences, socio-economic status, and gender bias. Edmund W. Gordon and Brenda X. Mejia examined resilience as a factor in overcoming obstacles to high academic achievement in their study by the same name. Within this study, Gordon and Mejia examine the role of resilience in the academic success of a student and define it to be, "the developmental process encompassing positive adaption by individuals despite significant

adversity."(TO, 2006) Resilience to adversity in mathematics is synonymous to perseverance in problem solving (Johnston-Wilder & Lee, 2010).

Students believe that if a problem cannot be answered within 5-12 minutes, and with a maximum of two steps, then the problem is not worth their time because it simply cannot be answered, and is labeled as "impossible to solve." (Mason, 2003) While time constraints from standardized testing (such as the ACT or SAT) and the amount of homework assigned by a student's other teachers reinforce the student's intrinsic desire for an immediate solution, few meaningful exercises in the 10th grade Geometry curriculum can be solved successfully within the 5-12 minute window and two-step solution described by Mason; especially by a student who is just being introduced to the world of postulates, axioms, and theorems which make up high school Geometry.

Student's negative attitudes and beliefs on problem solving are further reinforced by the feelings of being lost, frustrated, humiliated, and defeated during difficult problem solving, in conjunction with remembrances of previous failed attempts at problem solving (Lehman, D'Mello, & Person, 2008). While there is a lack of conclusive research delineating the effects of specific emotions on problem solving outcomes, Lehman hypothesized that a problem solving method that responds to the student's negative emotions by directing the student with hints to diffuse the confusion and alleviate the frustration experienced would be the most effective framework for developing problem solving ability and subsequent perseverance in students. Such a system would provide the necessary cognitive scaffolding while allowing the student to conquer the negative emotional aspects of the difficult or unfamiliar problem solving.

In the case of female, minority, and low-income students, the lack of perseverance in problem solving is attributed to not only the emotional state of the student, but also the social

constructs and expectations placed upon members of these gender and socioeconomic classifications (Lubienski, 2000). In Lubienski's study on socioeconomic class and students approaches to problem solving, she demonstrates that higher socioeconomic students displayed intrinsic motivation to solve the problems and struggle with mathematical ideals noting:

> Lower socioeconomic students tended to say that they would become frustrated and give up when 'stuck,' whereas higher socioeconomic students often said that they would think harder about the problem or just interpret it in a sensible way and get on with it.

Lubienski's observations coincided with this researcher's own interpretations of problem solving impetus in the studied student body. As explained by Lubienski, students in the lower socioeconomic strata preferred to be told "the rule" to solve the problem quickly rather than demonstrating a willingness to venture into creative means of problem solving. Furthermore, female students of lower socioeconomic status were the most likely to internalize any confusion or frustration felt during the problem solving process and would, in turn, "shut down" thereby removing themselves from the problem solving incident. Lubienski hypothesized that the difference in intrinsic motivation and willingness to be creative when contrasting the problem solving methods of higher socioeconomic status students with those of low socioeconomic status was born out of the parent-child interactions that each student experienced. Students of higher socioeconomic status were afforded greater autonomy in decision-making by their parents, and were permitted to "make mistakes" without the perception of causing the family or themselves impairment or financial trouble. Students of high socioeconomic status also had a higher trust of authoritarian figures, such as a teacher, affording them a level of comfort in their problem solving experimentations and failures that was not experienced by those students in the low socioeconomic status.

Priyanka B. Carr and Claude M. Steele explain that the student-perceived threat of being negatively stereotyped in an academic environment drains the student's energies and willingness which allow for creative and inventive problem solving to take place, resulting in an uncompromising problem solving approach and an impending collapse of perseverance in problem solving referred to as "inflexible perseverance" (Carr & Steele, 2009). The negative stereotype feared by the student is constructed and defined within the student's psyche as a result of a conglomeration of previous problem solving experiences, race, gender, socioeconomic status, family interactions and structures, and academic experiences. This absence of flexibility in problem solving studied by Carr and Steele is directly related to the preference of low socioeconomic students wanting "the rule" to solve a problem versus the willingness to explore, create, and experiment as noted in the previously noted study (Lubienski, 2000).

2.2 Scaffolding

As stated in the Introduction, scaffolding provides a predictable inquiry framework through which students fulfill expectations regarding sense-making, personal ownership, self-monitoring, and justification for their thoughts and solutions (Clark, 2008; Goos, 2004). Scaffolding is an educational technique which encourages the teacher to act in the role as an informal tutor to get the student "on their feet" and then gradually withdraws tutorial supports (Kalina & Powell, 2010). This gradual withdrawal of support allows the student to build confidence by experiencing success in their problem solving attempts and in their independent problem solving abilities, while building the cognitive organizational skills necessary to recall the information learned, therefore allowing the student to apply the information or "tools" necessary to successfully solve the problem at hand (Van De Pol et al., 2010).

Students who possess the skills to organize their subject knowledge were shown to be consistently better problem solvers and could recall a substantial amount of their available knowledge when prompted to do so (Lawson & Chinnappan, 2000). Organization in problem solving is key to success because our short-term memory can only handle 5-9 active items at one time (Novak & Cañas, 2006). Novak explains how the items in our short-term memory, or the newly acquired information is processed into our long-term memory by stating:

> While all memory systems are interdependent (and have information going in both directions), the most critical memory systems for incorporating knowledge into long-term memory are the short-term and "working memory." All incoming information is organized and processed in the working memory by interaction with knowledge in long-term memory (Novak & Cañas, 2006).

Students need to move newly acquired knowledge from short-term memory into their long-term memory so the information can be recalled at a later time. Therefore, to structure large bodies of knowledge requires an orderly sequence of iterations between working memory and long-term memory as new knowledge is being received (Anderson, 1992).

Given the myriad of reasons why a student chooses to "give up" when solving a math problem and the research showing the necessity for scaffolding, affective response to counteract the possible negative emotional state of the problem solver, and direction to provide positive affirmation of the attempt, the teacher is left to construct a teachable and sustainable method of problem solving to students which allows concepts and methods to be understood and applied, allows students a means of organizing then applying their knowledge, gives flexibility which addresses multiple types of problems to be solved, and exercises a methodology which is easily repeated and adapted across the curriculum.

2.3 The Engineering Method

Recall in the Introduction, I talked about attending a workshop where I was exposed to a problem-solving model called the Engineering Method of problem solving. What follows is a review of the literature regarding its origin and possible classroom applications.

The Engineering Method (Boston, 2008) incorporates the practices detailed by the Common Core State Standards in addition to the processes and schema outlined by educational and cognitive researchers for the development of critical thinking skills (Koen, 1985; Lou, Shih, Ray Diez, & Tseng, 2011; Tallman & Gray, 1990). This process of six steps has been identified by the engineering educators (Dym, Little, Orwin, & Spjut, 2004) and adapted by this researcher for student-use in mathematical problem solving.

1. State what you are trying to accomplish.
2. What do you know and what do you need to know?
3. Formulate a plan of attack.
4. Implementation of their plan
5. Evaluate your results.
6. Draw conclusions based on your solution

In his book written for the American Society for Engineering Education, Definition of the Engineering Method, Billy Vaughn Koen states that the engineering method is an adaptation of the scientific method and defines the engineering method to be:

> "The strategy for causing the best change in a poorly understood or uncertain situation within the available resources" (Koen, 1985).

Koen reasons that the evolution of the scientific method into the engineering method was due to the different, yet similar missions of science and engineering. Koen asserts that the mission of science is to find *the* answer, while the mission of engineering is to find *an* answer.

The engineering method of problem solving in a classroom utilizing inquiry-based, problem-centered instruction has been shown to be an effective mode of instruction for

producing gains in general academic achievement and for developing critical thinking skills in traditional subject areas such as mathematics (Prince & Felder, 2006). Research conducted by Michael J. Prince and Richard M. Felder on inductive teaching and learning methods found the following effects:

> The implication is that students may acquire more knowledge in the short term when instruction is conventional but students taught with PBL (Problem-Based Learning) retain the knowledge they acquire for a longer period of time. (Prince & Felder, 2006)

Further analysis of the studies documented by Prince and Felder found that while problem-based learning fostered the positive effects necessary to facilitate a positive development of problem solving ability and perseverance, there remained the need for a longitudinal study investigating the effect on content knowledge:

> Individual studies have found a robust positive effect of PBL on skill development, understanding the interconnections among concepts, deep conceptual understanding, ability to apply appropriate metacognitive and reasoning strategies, teamwork skills, and even class attendance, but have not reached any firm conclusion about the effect on content knowledge. (Prince & Felder, 2006).

Inquiry based instruction in a mathematics classroom has been found to be an effective means to teach students to speak and act mathematically, think critically, and to persevere through difficult problems by establishing a familiar and safe means of exploration (DeBellis & Goldin, 2006). The bundling of mathematics problems with engineering problem solving strategies appears to be a natural evolutionary step for the mathematics teacher to prepare their students for college and professional readiness (Fairweather, 2009). Practical instructions for taking the method into the classroom are lacking.

CHAPTER 3: SETTING AND BACKGROUND

In this chapter, I will describe the two settings in which this study took place, and the research population of the study. The second section focuses on the preliminary work that led to the development and implementation of the graphic organizer.

3.1 Populations and Settings

The subjects of this study were students of my 10th grade Geometry and Honors Geometry courses at both Breaux Bridge High School during the 2011-2012 school year and at Northside High School for the 2012-2013school year. Breaux Bridge High School is a Louisiana public school located in the St. Martin Parish School District, St. Martin Parish, in the rural fringes of the City of Breaux Bridge. There were 853 students at Breaux Bridge High School attending Grade 8 through Grade 12 the 2011-2012 academic year. Students who were eligible for free lunch total 448 students while the number of students who qualified for reduced-price lunches totaled 61. The student population eligible for free or reduced lunch was 59.67% of the total population, allowing the school to be classified as a Title 1 school according to Federal Department of Education guidelines. Ethic makeup of the student population shows the 442 White/Caucasian students to be 51.82% of the population, 395 African American students comprise 46.31% of the student population, and 12 Hispanic/Latino students made up 1.41% of the total student population. The remaining 0.46% was comprised of American Indian/Alaskan or those students identified to have two or more races. Enrollment by gender indicated 436 male students. The full-time educational faculty at Breaux Bridge High School is 48.16 with a student to teacher ratio of 17.71:1. (U. S. D. o. Education, 2013).

The Louisiana Department of Education School Performance Rating 2011-2012 rated Breaux Bridge High School as a “C” school with a baseline School Performance Score of 96.4.

Both the Growth Target and Adequate Yearly Progress were rated as "Not Achieved." 37% of the student population was indicated to be "on or above grade level" in English, while only 36% of the student population was indicated to be "on or above grade level" in Math. Current graduation rates for the school are at 71% with a graduation index of 204 students receiving a high school diploma or GED. The college readiness indicators show an average ACT score out of 36 points was to be 18.6 points with not all students participating in the testing, and the PLAN test for 10th graders indicating an average score of 15.1 points out of a possible 36 points (L. D. o. Education, 2013).

Northside High School is located in the northern portion of Lafayette Parish in Lafayette, Louisiana, and is governed by the Lafayette Parish School System. The Lafayette Parish School System is comprised of 47 school servicing 30,218 students in Lafayette Parish. Northside High School's student body of 907 students, grades 8-12, is comprised of 858 students identifying themselves as African American, 43 students identifying themselves as Caucasian (5%), and with 6 students identifying as American Indian, Asian, or Hispanic (0.4%). Enrollment by gender indicated 447 male students. Northside High School is a Title 1 school with 704 students (77.6%) eligible for free or reduced lunch by Federal Department of Education guidelines. The full-time educational faculty of Northside High School consists of 56 classroom teachers to produce a student-teacher ratio of 16.2:1 (U. S. D. o. Education, 2013).

The Louisiana Department of Education School Performance Rating 2011-2012 rated Northside High School with a letter grade of "D" and a School Performance Score of 76.7. Both the Growth Target and Annual Growth Target were not achieved. 44% of all students were identified to be at or above grade level achievement in English, while only 38% of all students were identified as being at or above grade level in Mathematics. Current graduation rates for

Northside High School are at 60% with 123 of 237 seniors receiving a high school diploma or GED. The College Readiness indicators show an average ACT composite score of 17.3 out of 36 possible points, and the PLAN test for 10^{th} graders indicating an average score of 15.3 points out of a possible 36 (L. D. o. Education, 2013).

The research population of 89 students contained 23 Honors Geometry and 24 Geometry students from Breaux Bridge High in addition to the 22 Honors Geometry and 20 Geometry students from Northside high school. Students were characteristic of the typical classroom populations and represented the comparable socioeconomic, gender, and racial properties occurring in both schools. Students were selected for inclusion in the study by completing and returning both the parental and student permissions forms required to be included in the study. Participation in the study was completely elective without privilege or punishment for their participation.

Both high schools operated on a 4x4 block schedule where students attend 4 classes daily with each class having duration of approximately 90 minutes. Each class spans one semester consisting of two 9-week grading periods.

Student achievement histories on state administered tests, such as the LEAP, and Algebra1 End of Course Exam, were examined for the body of students included within this study. The statistics for achievement levels of the research population included in this study for the LEAP test is shown in Table 1 and for the Algebra End of Couse exam in Table 2.

Table 1: Cumulative LEAP Test results for Research Population 2011-2013

Proficiency Rating	Student Achievement Levels on the LEAP Test
Advanced	0
Mastery	5.36%
Basic	42.86%
Approaching Basic	35.71%
Unsatisfactory	16.07%

Table 2: Cumulative Algebra 1 End of Course Examination results for Research Population 2011-2013

Proficiency Rating	Student Achievement Levels on Algebra 1 End of Course Examination
Excellent	7.69%
Good	30.77%
Fair	42.31%
Needs Improvement	19.23%

The State of Louisiana defines a student to be proficient in the subject matter assessed if the student achieved a rating of "Good" or "Excellent" on the End of Course examination. Of the students in this research for which testing results are available, 61.54% failed to achieve state-defined proficiency. Testing histories were not available for all students due to out-of-state transfers or transfers from schools where LEAP and EOC testing does not occur, such as in private and parochial schools.

3.2 Preliminary Work

As discussed in the introduction, many high school mathematics students lack the perseverance and resilience necessary to endure through difficult, multi-step, and open-ended problem solving ventures. Many students will not venture to attempt a solution to the problem presented without knowing they are completely correct prior to finding the solution. Students opt to leave a question blank on an assessment or assignment, rather than attempt a solution. As previously stated, the Common Core State Standards recognize this as an issue and have given high priority to student perseverance through difficult and multi-step problem solving in their standards for student achievement (National Governors Association Center for Best Practices, 2010a).

In the summer of 2010, I began to research ways to strengthen my student's perseverance in problem solving. Within this research, I first needed to understand why students chose not to

persevere, what factors influenced their conscious and subconscious decisions to give up, and a means of mitigating the detractors from the student's problem solving efforts. I quickly found a plethora of information on metacognitive, emotional, historical, geographical, socio-economic, and gender factors relating to the lack of student perseverance. However, on the whole, the proposed "solutions" to these problems were either well beyond the scope of a single classroom teacher, or they were completely impractical for classroom implementation. An exception to the general impracticality of the solutions presented was the use of scaffolding.

As reported in the literature review, research shows the value of scaffolding to support a student's learning of new material and to connect newly acquired knowledge with knowledge the student already possessed. Generally, the instructor provides the scaffold to the student by guiding them onto the correct problem-solving path through each and every facet of the problem. However, I wondered what would happen if students were trained to scaffold the material for themselves. I set out to train students to scaffold their own problem solving routine through repeated utilization of a problem solving process, the Engineering Problem Solving Method.

The six steps of the Engineering Problem Solving Method were presented to my students at Breaux Bridge High School in the form of a class discussion with the steps projected on the board for reference. The discussion was intended to start students reflecting on their problem solving techniques, and to identify where their personal challenges would interfere in the problem solving process. The steps were presented in outline form with the problem-solving correlations written-in to help students make the connection, as illustrated in Appendix A.

As I have previously mentioned, students did not successfully adopt the method. In no uncertain terms, students said that the six steps were not an asset because they were in addition to the steps they needed to solve the problem. They felt that the steps were just more work and

more things they needed to remember, and they let me know that I was “out of my mind” with several picturesque descriptions of where they believed my mind to be located. This crisis led me to modify the plan to incorporate the graphic organizer. The visual appearance of the method’s six steps did not convince students that they had been alleviated of extra work, however, the outline structure of the method parallels the scaffold structure for problem solving skill development. The goal remained the same: if students could make the problem solving method a habitual sequence of internal procedures, they would build confidence in both their mathematical and general problem-solving skills, thereby mitigating many of the emotional and metacognitive detractors they currently faced.

A reformatting of the problem solving method into a more palatable format was in order. The solution I devised is illustrated in Figure 1, page 20, and a full-sized example of the graphic organizer is included in Appendix B. For details about the design of the graphic organizer, please see Chapter 4: Process and Instrument Overview. I believe the graphic organizer will be more useful and is used more when the problem demands more short-term memory work and has less support from long-term memory.

CHAPTER 4: PROCESS AND INSTRUMENT OVERVIEW

In this chapter, I will explain the process in which I had planned to carry out this research, the motivations for and subsequent development of the graphic organizer, and a description of the three lessons selected for observation in this study.

4.1 Process

Students were introduced to the graphic organizer described in the previous chapter. The three assignments of coursework selected for evidence of student work and observation range from a simple writing assignment at the very beginning of the semester, to a more complex problem reviewing the concepts radius, sector area, and the of area of a circle, and concluding with a very complex, multi-step, and open-ended assignment at the very end of the curriculum unit involving surface area and volume of three-dimensional figures.

Students also participated in several pre-semester and post-semester surveys, the results of which will be compared and analyzed in upcoming chapters. Student data from state administered tests such as the LEAP and Algebra 1 End of Course examinations is compared to student achievement on the Louisiana End of Course examination for Geometry administered at the conclusion of the course.

4.2 The Graphic Organizer

The graphic organizer is a template divided into four sections on which students can sort, evaluate, and compile thoughts and strategies. The graphic organizer enables students to tangibly sort the pieces of the puzzle and to draw, sometimes quite literally, connections between ideas. The organizer used in this study was developed to assimilate the directives of the School Improvement Plan, incorporate the organization found in 6 steps of the Engineering Problem Solving Method mentioned in the literature review, and making the format palatable to students.

As part of the School Improvement Plan (SIP) at Breaux Bridge High School, teachers were directed to implement and develop writing across the curriculum. The English department had adopted the use of the Four Square Writing Method developed by Judith A. Gould, Evan Gould, and Mary F. Burke based on its documented success to develop critical thinking in writing and organization of ideas into coherent written communication (McCarthy, 2010). The Four Square Writing Method is a graphic organizer which allows students a means of organizing their thoughts and data to construct meaningful, well-written paragraphs (Gould & Evan, 1999). Students were familiar with the format of the Four Square Method, as the majority of students had used this format since junior high. The intended purpose of the graphic organizer within this Geometry class was not to write grammatically correct, but to allow purposeful organization of a student's thoughts, ideas, formulae, and mathematical computations providing the scaffolding necessary to persevere through the problem.

This organizer was to be practiced and referred to consistently in instruction, problem solving, classwork assignments, home assignments, and formal assessment. Student use of the organizer was expected to be on-going and student-directed. Students would utilize the graphic organizer in the form of a pre-printed wipe-off board to assist with problem solving (Appendix A). Student utilization and visually-observable dependence upon the graphic organizer was observed and a journal was kept in addition to the standard monitoring done by a classroom educator. Instructor observation of student implementation of the organizer was monitored visually and by probing students about its use, or lack thereof, as the case may be.

The organizer (See Figure 1) was printed onto cardstock, laminated, and given to each student along with a wipe-off marker for writing on the organizer. A full-sized version of the template is located in Appendix B. Students were given the option to use the wipe-off board in

class and were given several paper copies of the organizer to use at home or in study hall. Though the use of the organizer was optional, students were required to provide some evidence of effort to show before asking the instructor for help, and entries on the organizer were acceptable.

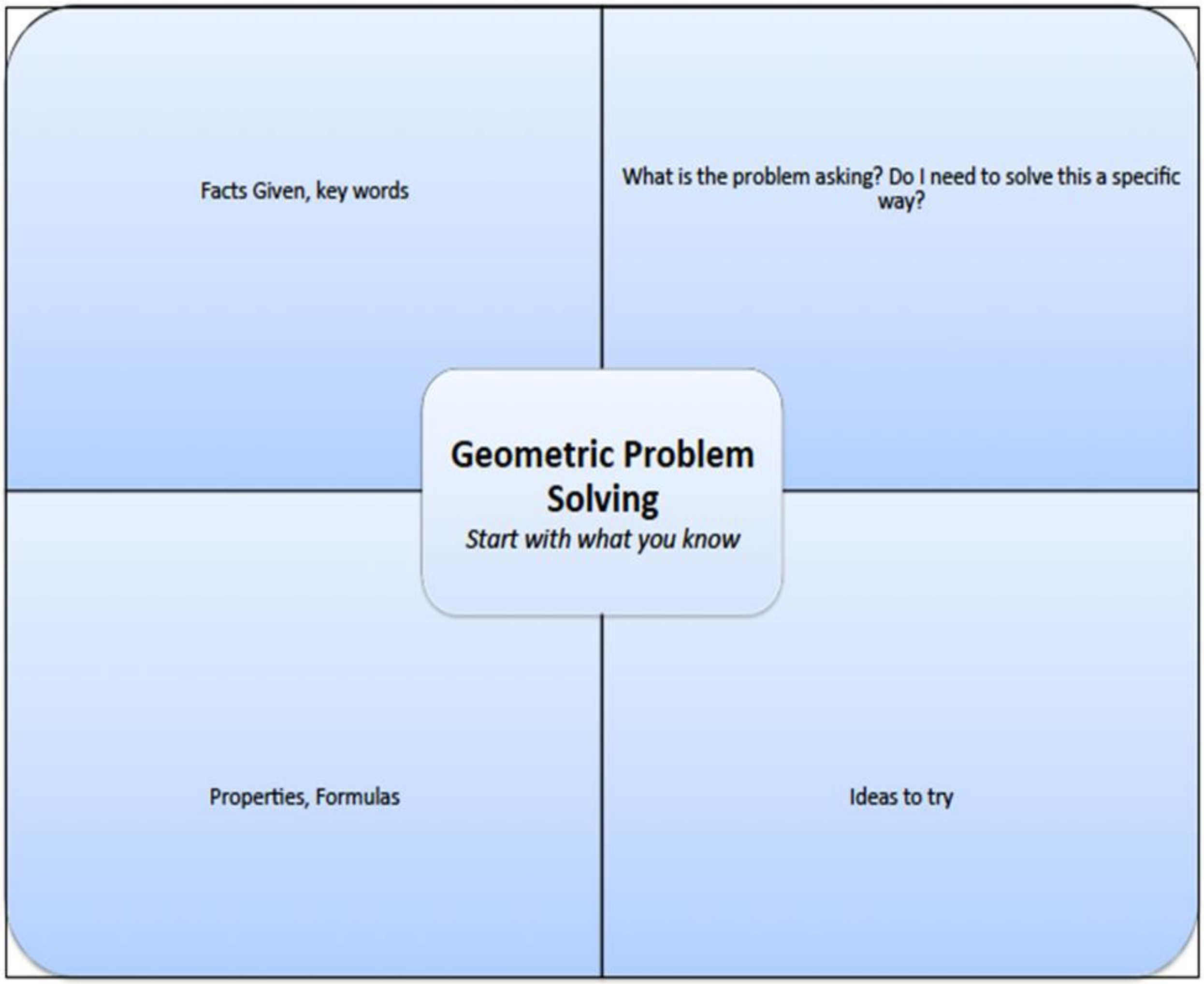


Figure 1: Problem Solving Foursquare Template

4.3 Selected Assignments

The following subsections provide descriptions of the three assignments chosen for observation in this study. Louisiana Grade Level Expectations and their Common Core correlations are provided for each of the three assignments. The assignments increase in

complexity from the very basic making of a sandwich to the very complex task of finding the volume of an irregular, yet common, household object.

4.3.1 Assignment 1: Making a Peanut Butter and Jelly Sandwich

The construction of a peanut butter and jelly sandwich is a very tangible and student-understandable means of demonstrating the need for organization of process and thought necessary in the satisfactory completion of a problem-solving task. Students are familiar with the seemingly “basic” task of making the peanut butter and jelly sandwich, but have they ever examined the actual complexity of the task at hand? This task requires a student to use very little newly acquired knowledge addressed the mathematical processes as enumerated within the Common Core State Standards for Mathematics, High School Math:

> #1 Make sense of problems and persevere in solving them.
> #3 Construct viable arguments and critique the reasoning of others.
> #5 Use appropriate tools strategically.
> #6 Attend to precision.
> #7 Look for and make use of structure.
> (National Governors Association Center for Best Practices, 2010b)

This exercise was performed during the first week of the semester. Students were provided with the scenario that an alien has landed on Earth. In order to save the planet from certain doom, students must provide the alien with viable written instructions on how to construct a peanut butter and jelly sandwich. The following sandwich making materials were supplied to each group of two students: One paper plate, four pieces of bread, one jar of peanut butter, one jar of jelly, one spreading utensil (knife or spoon, depending on school district policies). Student teams were given ten minutes to document, to the best of their abilities, the steps necessary to construct the planet-saving sandwich without the aid of the graphic organizer. Students were not prompted or cautioned to be specific or otherwise. At the end of ten minutes,

the student responses were collected. The instructor randomly selected a student's instructions to follow in making the sandwich for demonstration to the entire class. After observing the instructor's presentation of student instruction, students critiqued their own writing and discussed with classmates how to improve their sandwich making instructions. Students were given the assignment to re-write their instructions while incorporating the notes provided by the peer-critique. The goal of this exercise was to illustrate to students why their written explanations must be clear and precise, and to facilitate peer and self-critique of work.

4.3.2 Assignment 2: Perplexed about Pizza

Table 3: GLE and Common Core Correlation for Perplexed About Pizza

Louisiana Grade Level Expectation	GLE Text	Aligned Common Core Standard
M10.4	Use ratios and proportional reasoning to solve a variety of real-life problems including similar figures and scale drawings.	G-SRT.5
G.2.H	Solve problems and determine measurements involving chords, radii, arcs, angles, secants, and tangents of a circle	G-C.1, G-C.5
G.6.H	Develop formal and informal proofs (e.g., Pythagorean theorem, flow charts, paragraphs)	G-MG.3

This activity was presented to the students mid-semester as a refresher of circles and their areas. Standards addressed by this exercise are found in Table 3. The activity required the use of some newly acquired knowledge, however, students had to rely on past learning to complete the task. Students were challenged to determine the "best deal" when presented with a real-life application problem involving the area of a circle. Students must determine if they are getting their money's worth when they ordered two 8" diameter pizzas versus ordering one 16" pizza. Students were instructed to justify their decision using mathematical and graphical evidence they created from the information given in the problem. Students were also introduced to the concept of sector area when asked about to compare the size of the slices of pizza.

Students were supplied with the worksheet, their problem-solving wipe off board, a drawing template for their circles, and a calculator. Students were presented with the problem, then they were immediately asked to pick sides by standing on one side of the line or the other, depending on their decision. Did they agree that buying 2 8" pizzas is the same thing as ordering a single 16" pizza, or did they disagree? Once their side was chosen, students needed to work together in order to mathematically and visually prove their decision. Students were given 30 minutes to complete their work on the task. Ten minutes were given to students who wished to present their ideas to the class, culminating with the instructor going over the correct and incorrect solutions presented.

4.3.3 Assignment 3: Finding the Volume of an Irregular Object

This exercise addresses the following Louisiana Grade Level Expectations for 10th Grade Mathematics and corresponding Common Core alignment (Table 4). Students performed this exercise during the final week of the course as an exercise in open-ended and complex problem solving. The solution of this problem required the student to utilization of a large amount of short-term memory.

Table 4: GLE and CCSS Correlation for Finding the Volume of an Irregular Object

LA Grade Level Expectation	GLE Text	Aligned Common Core
M10.7	Find volumes and surface area of pyramids, spheres, and cones	G-GMD.3
M10.12	Apply the Pythagorean Theorem in both abstract and real-life settings	G-SRT.8
None	Apply geometric methods to solve design problems	G-MG.3

In preparation for this activity, students practiced measuring and calculating the volumes of polyhedra such as cones, spheres, and cylinders using supplied formulae. This activity focuses on finding the volume of an object for which the students have not learned or received a

volume formula. In this exercise, students were challenged to adapt existing knowledge of volume formulas to the shape they believed most closely resembling the object. In this case, the object was a plastic, 16oz. SOLO™ party cup, commonly found at any grocery or party supply store. Students were not given the volume of the cup, nor was the volume marked anywhere on the cup. Working in pairs or on their own, (student choice), it was up to the students to create an accurate means of measuring the cup's dimensions, note the dimensions on their sketch, and devise a mathematically sound method of calculating the cup's volume.

Students utilized a diagram of cup in the provided work packet in order to track measurements and make notes about solution methods and observations. Students were supplied with a ruler showing both US Standard and metric measurements and a protractor. The instructions of the activity noted students should record all linear measurements in centimeters to the nearest tenth, the most accurate measurement available with the tools supplied to them. Angle measurements would be made using the nearest whole degree, again, reflecting the maximum accuracy of the tool provided. Student work was graded on accuracy of method, accuracy of measurement, and by overall outcome as determined by the actual volume of the cup versus the calculated volume. Students were not directed by the instructor in how to go about their process of measuring and calculation, but were encouraged to be creative, be accurate, and, if they got lost, to refer back to their graphic organizer to find a way of successfully completing the task. This activity was completed in one 90-minute class period in block scheduling. Lesson plan, activity documents, and instructions are located in Appendix E.

CHAPTER 5: DATA

In this chapter I present the data gathered throughout this study. I will illustrate the usage of the graphic organizer, data collected from student work samples, standardized test data, survey data, and concluding with observational data.

5.1 Usage Data

Recall from the previous chapter that use of the graphic organizer was essentially voluntary. Student use of the graphic organizer for problem solving during classwork was recorded using the entire class as the population. Student use was compared to the number of students in attendance for the entire class period and percentages were compiled by the week. Figure 2 illustrates the classroom usage of the organizer.

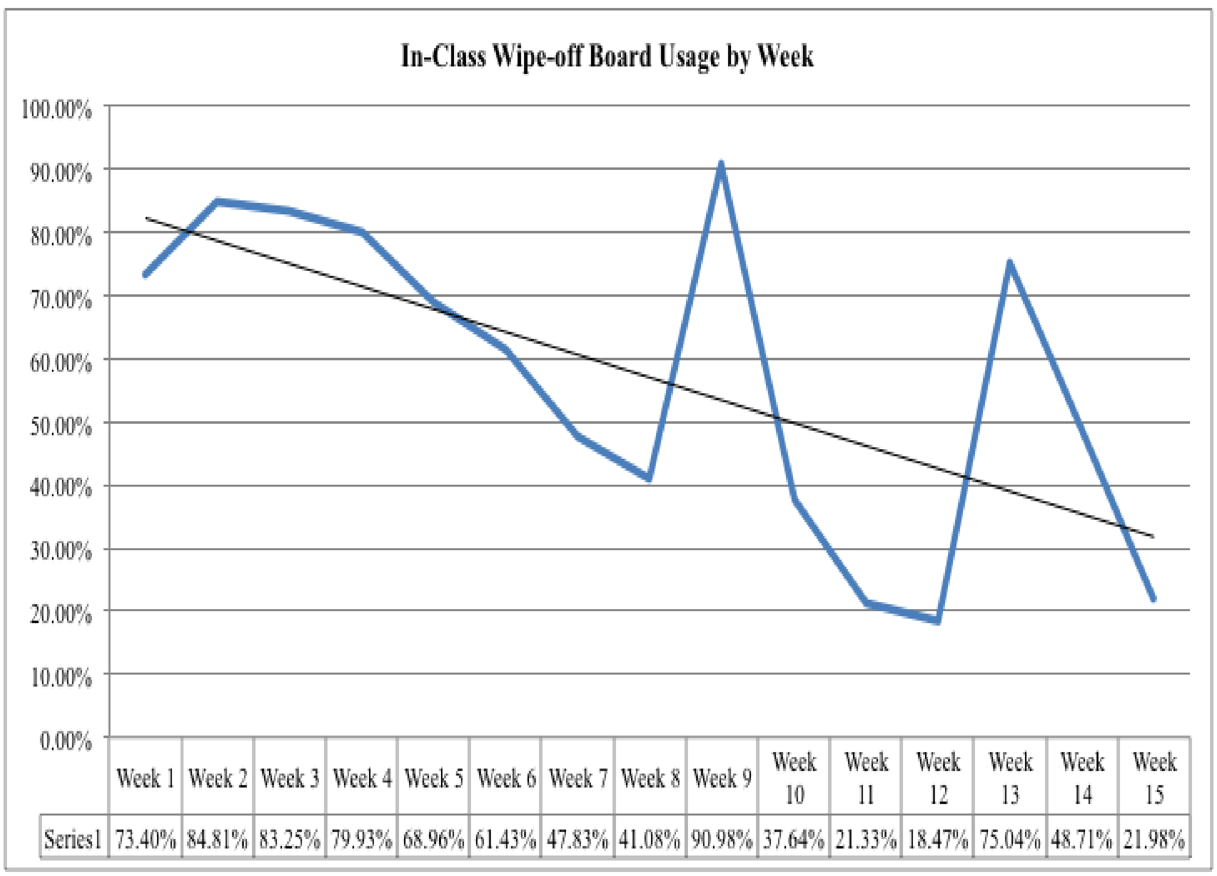


Figure 2: Classwork usage of the wipe-off board by week

Student use of the paper version of the problem solving method was surveyed by asking students to put a star on the left hand side of the their homework paper if they used the method at any time while doing their homework. The number of stars was compared to the number of assignments received and then compiled into a weekly percentage. Figure 3 illustrates the student reported use for the organizer during homework assignments.

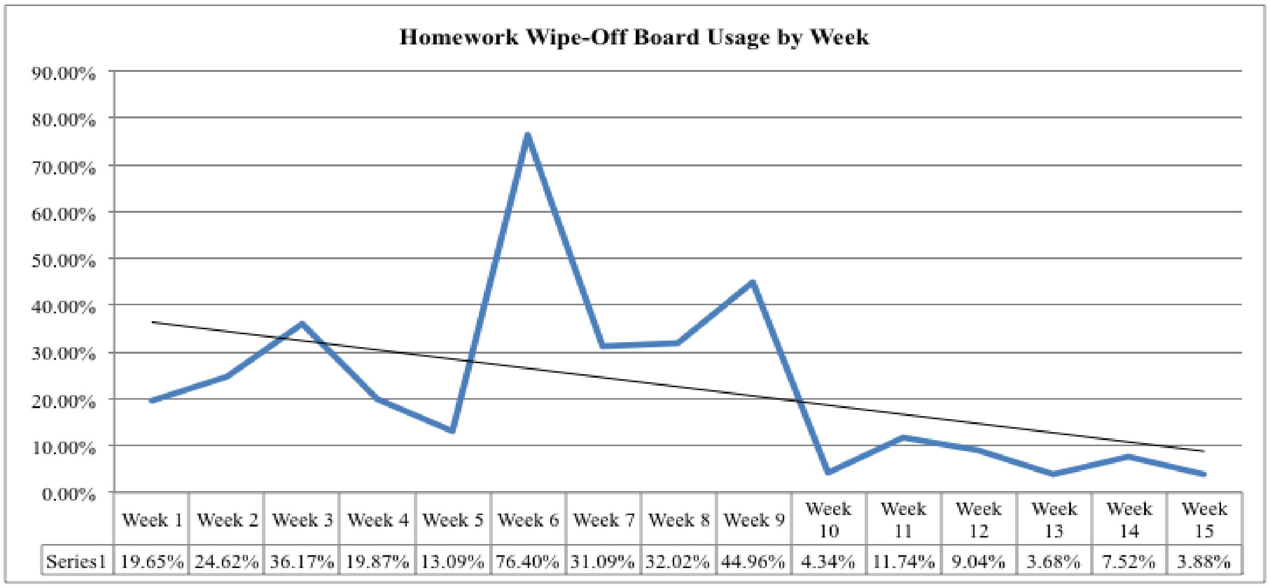


Figure 3: Homework usage by week

5.2 Student Work

This section contains the description of student work samples for the three selected assignments, beginning with Peanut Butter and Jelly, then on to Perplexed by Pizza, and concluding with Finding the Volume of an Irregular Object.

5.2.1 Peanut Butter and Jelly

The initial set of sandwich-making instructions provided by the students was, predictably, terse and inaccurate. Student submissions showed evidence of widespread assumptions that the person building the sandwich had previous experience and knowledge of sandwich building. The extensive use of pronouns in exchange for precise names of objects created confusing and

technically incoherent instructions for a person lacking previous experience in sandwich making. Further confusion was caused by student omissions of the break down or annotations of the physical actions necessary to successfully construct the sandwich with the items provided, as evidenced in Figures 4 and 5.

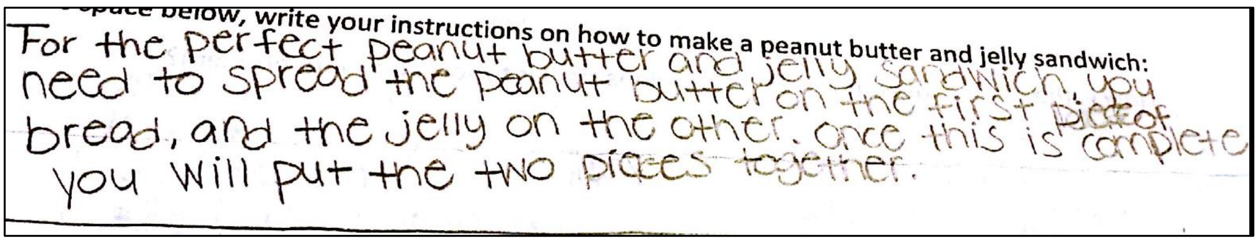

…pace below, write your instructions on how to make a peanut butter and jelly sandwich:
For the perfect peanut butter and jelly sandwich, you need to spread the peanut butter on the first piece of bread, and the jelly on the other. Once this is complete you will put the two pieces together.

Figure 4: Student #1 First Submission for PB and J

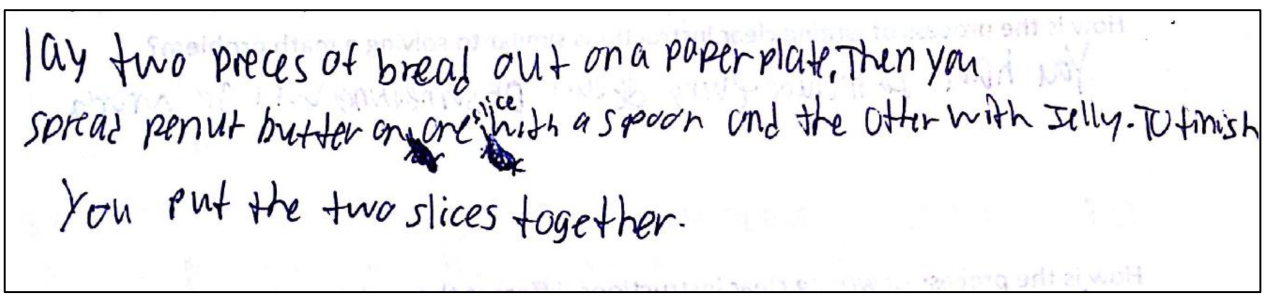

lay two preces of bread out on a paper plate. Then you spread penut butter on one slice with a spoon and the other with Jelly. To finish You put the two slices together.

Figure 5: Student #2 First Submission for PB and J

Student critique of peer work was, at first, passive. Students appeared embarrassed by their work and unwilling to share with each other. I observed several instances of students glancing over a peer's instructions and providing little suggestion on how to improve it. Students were reminded that "everyone was in the same boat" and that each member of the class had the opportunity to be instrumental in the improvement of another's skills. Students did begin to share more openly and an honest dialogue of critiquing of their peer's work began. Students identified the need to restrict the use of pronouns in technical writing to avoid confusion. Students also corrected each other's omissions of physical actions in their instructions. Student use of the graphic organizer was not observed during this exercise. When

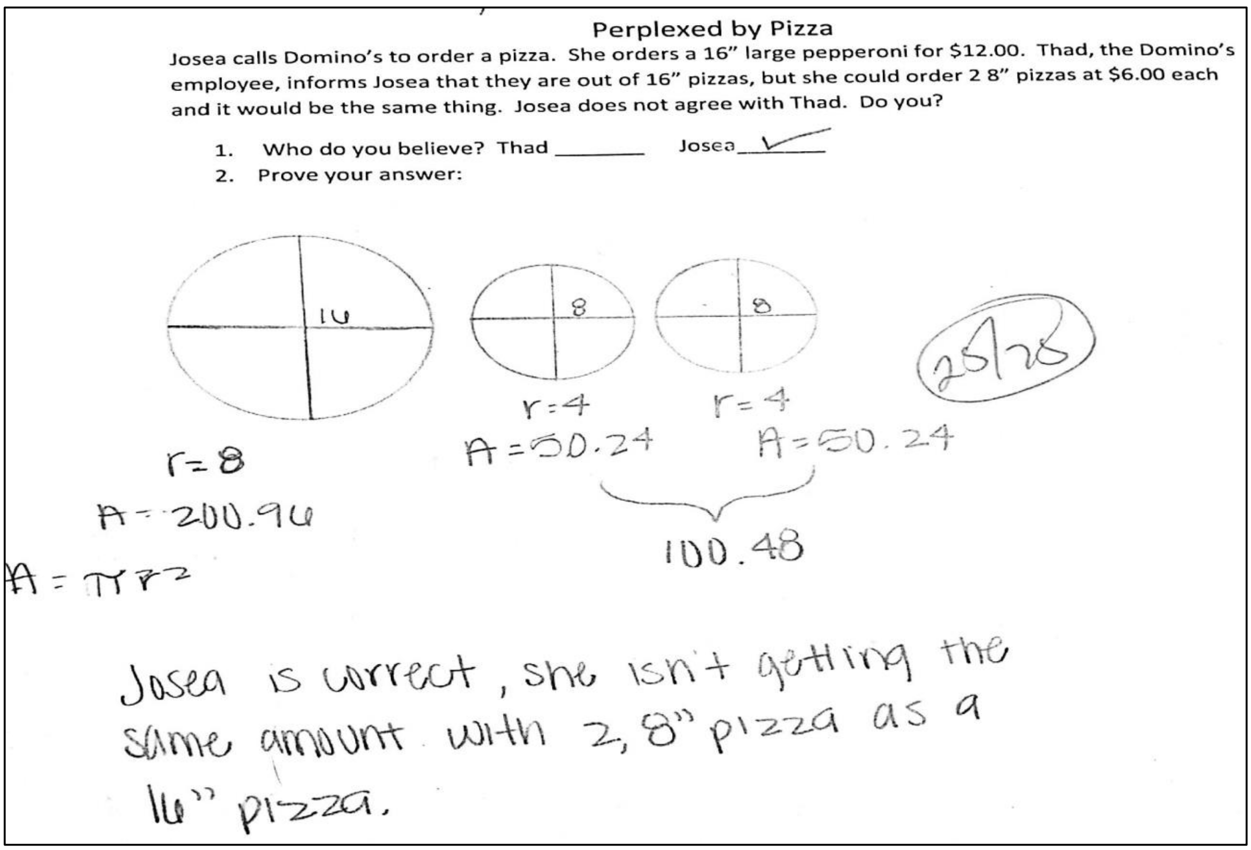
asked why they had chosen not to use the organizer, students replied that they found them unnecessary for this task.

Generally, final student submissions by were noticeably improved in both clarity and attention to detail. The use of pronouns and inaccurate language was dramatically reduced while detailed instructions for physical actions and the logical order of directions were greatly increased. Of the entire population of 195 students who participated in the activity, three refused to re-write their initial submissions and seven students did not submit their final instructions. Students did not use the graphic organizer during this exercise. When I inquired as to why they did not use the organizer, students replied that they did not need it. Students reported that the process of making a sandwich is not something they needed to practice.

5.2.2 Perplexed about Pizza

Students struggled with the idea that they needed to find the area of the pizzas in order compare the edible amounts they would receive in the competing orders. While monitoring student progress in the problem, I was alerted to the misconception regarding the sum of the diameters after I noticed “8+8 =16” written in the “Facts Given” compartment of the several organizers. Once I began to ask students about this equation, I understood that it was a common belief among students that because the sum of the diameters of the two 8 inch pizzas equaled the diameter of the 16-inch pizza, they would receive the same amount of pizza. Seeing this equation written on the organizer queued me to immediately address the error regarding the sum of the diameters. Students drew diagrams showing a scale model of the two 8” pizza versus the 16” pizza. I pointed out that you do not eat just the diameter of the pizza, you eat the area of the pizza. I then asked students to find out exactly how the diameter of the pizza affects the amount of pizza they can eat.

Those that chose to continue use of the wipe-off boards for the activity used them to write down the formulas for the circumference of a circle and for the area of a circle. It was not until students began to investigate the areas involved in the different orders that they began to see that there was a definite choice on which order provided the better value. Students that utilized the organizer shared their ideas with classmates by pointing to ideas and diagrams written on the organizer that were relevant to the discussion, although most students chose to make diagrams and show work on the worksheet provided as opposed to trying the problem on the wipe-off board. An example of student work for this exercise is provided in Figure 6.


Perplexed by Pizza

Josea calls Domino's to order a pizza. She orders a 16" large pepperoni for $12.00. Thad, the Domino's employee, informs Josea that they are out of 16" pizzas, but she could order 2 8" pizzas at $6.00 each and it would be the same thing. Josea does not agree with Thad. Do you?

1. Who do you believe? Thad ________ Josea ✓
2. Prove your answer:

16 8 8

25/25

r=8 r=4 r=4

A=200.96 A=50.24 A=50.24

100.48

A = πr²

Josea is correct, she isn't getting the same amount with 2, 8" pizza as a 16" pizza.

Figure 6: Student solution and diagram for Perplexed by Pizza

Most students continued on through Question #2 of the exercise without incident and correctly calculated the area of the pizzas to determine the 16" pizza was a better deal because it was double the area of the two 8" pizzas.

A new challenge was posed to the students in the third question. Question #4 of the exercise asks:

> “The 8” pizza is cut into 12 slices and the 16” pizza is cut into 8 slices. Which choice would give you the most food for your money? Explain your reasoning.

A number of students answered that the 12 slices would be a better deal because you get more slices. I asked if one slice from the 8” pizza contained the same amount of pizza found in a slice from the 16” pizza. Initially, the answer was that they contained the same amount. This answer alerted me that students had not grasped the idea of sector area. The students that were struggling with this concept to divide the diagrams they had drawn of the 8” and 16” pizzas into 12 and 8 equal pieces, respectively. Once they saw the slices drawn out, students corrected their error and were able to explain their reasoning appropriately to other students and for the purpose of the assignment.

Of the 183 students present for the assignment, 6 did chose not complete the assignment stating that did not know what to do or where to begin. These students were given the opportunity to complete the assignment at home for half credit, but none of the six returned a completed assignment.

5.2.3 Finding the Volume of an Irregular Object

In general, students were overwhelmed at the presentation of the activity and the work involved. Beyond the obvious exclamations of “That’s impossible!” and “We only have this class period to get it done?” many students expressed concern about how to begin the task, let alone complete it successfully in the time allotted. Students were reminded to refer to their Engineering process. Once armed with their wipe-off boards, students began to discuss the shape of the object. Similarities and differences to both the cone and cylinder were observed and debated while annotating their observations within their packet. Most students made the

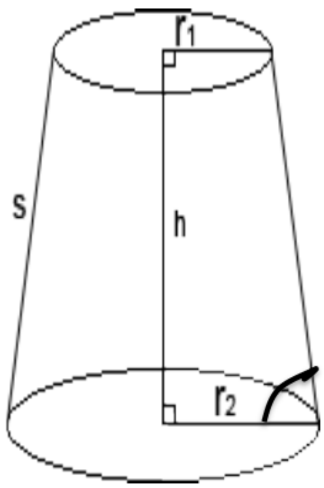
connection that the shape of the cup was a truncated cone, or, as one student stated, “a cone with the top chopped off.” Some students took a decidedly different approach, noting that the cup appeared to be a collection of cylinders of varying heights and circumferences stacked one upon the other. The differences in the observations brought about very different problem solving strategies to the students, and also allowed students the creativity to apply the geometric formulae in very different manners.

Students had no problem measuring the circumference of both the base of the cup and the lips of the cup. Most students measured the diameter of both the base and the lip and divided by two to ascertain the corresponding radii. Another group of students traced the circular forms of the base and lip onto their paper and made measurements from there. When the instructor observed students using the “tracing” method of measurement, students were questioned to discover that many of them had not taken into account that this method may introduce an unnecessarily high amount of error into their measurements. Some students stepped back and found a more accurate means of making the circumferential measurements while others continued using the tracing method to determine the radii. The rolled lip of the cup confused some students. This rolled lip created the opportunity to discuss the difference between the interior and the outer diameters, also known as the I.D. and O.D. The instructor questioned students, who were confused as to whether in the inner diameter or the exterior diameter should be used in their calculations, “Which measurement would correspond to where the liquid would be held?” This allowed students to reason for themselves the answer to their own question while providing a tangible explanation for the need of the specified measurement.

The majority of students wrestled with the difference between the slant height of the cup and the height of the cup. Many believed the two measurements would be exactly the same,

despite the numerous calculations and measurements they had made on cones and pyramids in the lessons prior to this exercise. Once the students were convinced that the measurements of slant height and object height would be different lengths they approached each measurement in varying ways.

Most students obtained their slant height by laying the cup on its side and placing the ruler on the cup's side so that the parallel measurement from the lip to the base could be read easily. Some students decided to take a trigonometric approach when calculating the slant height (See Figure 7). They utilized the angle created by the cup wall and cup lip in tandem with the



$$S = \frac{h}{\sin\theta}$$

$$S = \sqrt{(r_2 - r_1)^2 + h^2}$$

$$\theta = sin^{-1}\frac{h}{S}$$

Figure 7: Sample equations and methods used by students to find missing measurements

cup's height to create a trigonometric equation allowing them to solve for the slant height. Another group of students found the difference in the radii between the lip and the base of the cup, and then utilized this difference in tandem with the object's height to create a right triangle. Once the right triangle was created, students utilized the Pythagorean Theorem to calculate the slant height as the length of the hypotenuse. Conversely, several students used a trigonometric approach to find the angle created by the cup wall and lip. Using the height of the cup and the slant height, students were able to use the trigonometric inverse to find the measure of the angle.

Now that measurements have been made, it was the student's objective to find a means of calculating the volume of the cup. The students devised several different and interesting ways of approaching the problem from the aspect they felt most comfortable. Shape was the deciding factor for most students to determine the method of their approach. If the student felt the cup resembled a cylinder they approached the problem by either slicing the cup, or by creating two cylinders. An example of this method is illustrated in Figure 8.

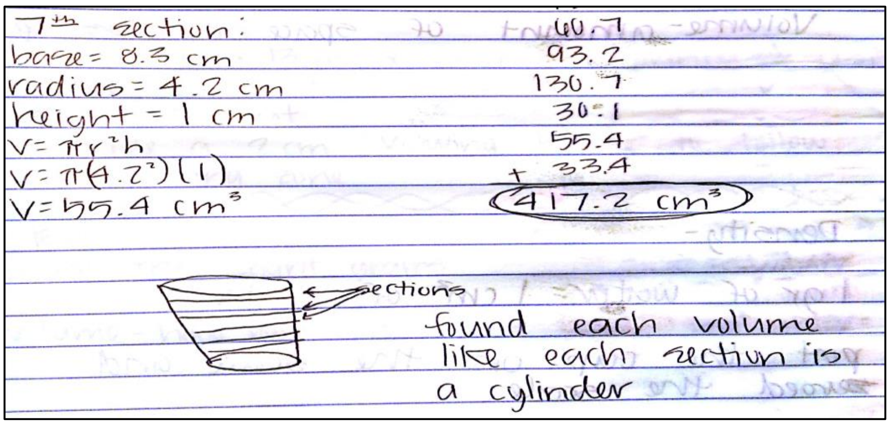


Figure 8: The "slicing" approach to finding the volume

Slicing the cup into a series of cylinders having a fixed height and a radius from the cup base to the cup lid was a popular solution method with students who approached the cup as if it was a pure cylinder. Some students utilized the height of the cup and the difference in the radii to determine a ratio of the rate of change for the radii. Other students determined a fixed height and continued to make radii measurements throughout the cup to determine the volume of their disks.

Envisioning the cup as a set of two cylinders, one large and one small was another approach to the volume problem. Students supposed that the radius at base of the cup would create a cylinder of a specific volume and the radius at the lip of the cup would create a cylinder of a greater volume. A student's illustration of this method is shown in Figure 9. After calculating the volumes of the cylinders, the difference between the volumes was found, divided

by two, and then either added to the volume of the smaller cylinder (cup base) or volumetric mean was subtracted from the volume of the larger cylinder (cup lip).

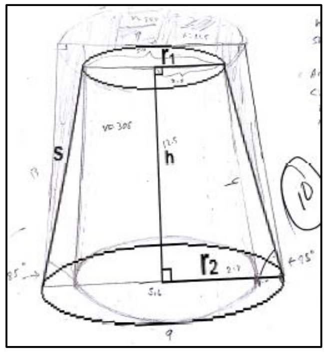


Figure 9: Student work using the large and small cylinder

Students who approached the problem as if the cup was a cone used several means of creating the “full cone” shape as shown in in Figure 10. The students shown in Figure 10 resorted to taping two sheets of paper together and sketching their ideas on the paper because the board was not large enough to encompass their strategy. Some participants used straight edges attached to the cup to estimate the height of the cone, while others took the purely mathematical approach of finding the full cone’s height using the radius of the cup’s base and the angle created by the cup wall and the lip of the cup. At this point in the exercise, students found the volume of the larger cone and subtracted the volume of the smaller “imagined” cone to result in the volume of the cup.

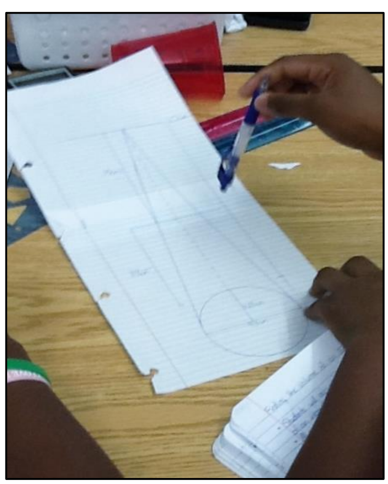


Figure 10: Student solution process illustrating two cones

Of the 183 students present for the assignment, all students comleted the assignment in the time allotted. However, four students received a grade of zero on the assignment because they admitted their work was copied from another student after I found them sleeping through the activity. At the conclusion of the activity, several students in different classes expressed a sense of pride in what they had accomplished. As one student said to me, "When we first started this (activity) I thought it was impossible. Now, I have a real sense of accomplishment!"

Student use of the graphic organizer was wide spread during this assignment. As witnessed previously, the students would show work on both the worksheet and the graphic organizer. Students uitlized the boards to draw out ideas for gathering measurements, methods of finding the volume of the cup, formulas, and trigonometric relationships. For many students, the graphic organizer served as a planning board as they decided how they would attack the problem of solving for the volume of the cup. The abundant sharing and comparing between students of their ideas and methods to find the measurements and volume were boysterious and educational. Students justified and defended their method by pointing to items written on the card and explaining its use in the solution process. The use of the boards allowed students to exchange their problem solving information without revealing their data for others to copy. For those students who attempted the "cone with the top chopped off" method of solving for the volume of the cup, students found the board was too small to encompass their drawing of the full cone, so they taped two pieces of paper together and continued working between the board and the taped paper.

5.3 End of Course Test Results

The End of Course (EOC) examination is administered by the State of Louisiana at or near the end of the high school Geometry course in all Louisiana public schools. Students are

graded on a point scale that ranges from 600 to 800 points, and then categorized by achievement levels as shown in Table 14.

Table 5: Louisiana Geometry End of Course Score Classifications

EOC Achievement Classification	Score Range
Excellent	731–800
Good	700–730
Fair	665–699
Needs Improvement	600–664

The test consists of three sections. The first section is made up of 25 multiple-choice questions on which students are not allowed to use a calculator unless specified by their state-recognized exceptionality and accompanying Individualized Education Plan (IEP). The use of a calculator is allowed on the remaining two sections for all students. The second section consists of three constructed response questions. The remaining section of the EOC test is comprised of 25 multiple-choice questions. There is no time limit for students to complete any part of the test. The State of Louisiana indicates that a student has passed the EOC when the rating of “Fair” is achieved. The State of Louisiana defines a student to be proficient in the subject matter if the student achieved a rating of “Good” or “Excellent” on the End of Course examination. School-wide results for both Breaux Bridge and Northside High Schools for the corresponding years are compared to the results for the research population in Table 15.

Table 6: Results for the Louisiana Geometry End of Course Examination

Geometry End of Course Results	Breaux Bridge High School 2011-2012	Northside High School 2012-2013	Research Population
Excellent	11%	8%	10%
Good	21%	23%	21%
Fair	35%	40%	40%
Needs Improvement	33%	29%	29%

5.4 Survey Data

Research population members participated in two surveys as part of this study: The Mathematics and Problem Solving Survey and the Student Study-Behaviors and Problem Solving Attitudes Survey. The remainder of this section consists of a brief discussion of each survey's content followed by the results of that survey.

5.4.1 The Mathematics and Problem Solving Survey

The Mathematics and Problem Solving Survey (Mason, 2003) (Appendix E) is a 5-point Likert scale survey consisting of 6 questions that cover student's general attitudes involving mathematics. Survey questions are listed below.

1. I can solve time-consuming problems.
2. There are word problems that cannot be solved using simple, step-by-step procedures.
3. Understanding concepts is important in mathematics.
4. Word problems are important in mathematics.
5. Effort can increase mathematical ability.
6. Mathematics is used in my daily life

Identical surveys were presented to students at the beginning and at the end of the semester. Survey results are shown in Figure 11.

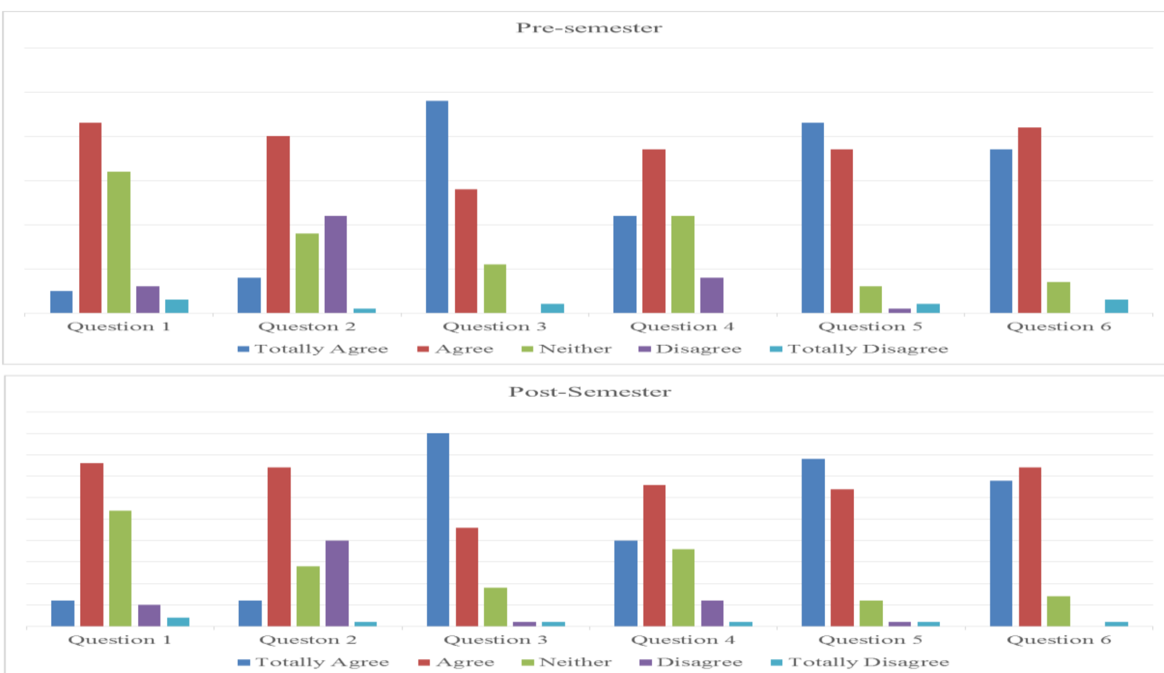


Figure 11: Mathematics and Problem Solving Survey Results

5.4.2 The Student Study-Behaviors and Problem Solving Attitudes Survey

The Student Study-Behaviors and Problem Solving Attitudes survey consists of a 26 question multiple choice format pre-semester survey (Appendix F) and a 27-question multiple-choice format post-semester survey (Appendix G). The pre-semester survey questions are identical to the post-semester questions, with the exception of the Question #27 being added to the post-semester survey. This survey was developed with the assistance of several colleagues to find out more about student study behaviors and attitudes.

Questions 1 and 2 ask students about the resources they use inside and outside the classroom to solve mathematical problems. Questions 3 and 4 ask students how much time they are willing to spend on a mathematical problem on a test and on their homework, respectively. Question 5 asks students why they leave questions on a test blank. Questions 6 through 14 ask students about their study behaviors when preparing for a test. Questions 6-14 were for my own information and analysis as a classroom teacher. The data collected from these 8 questions was not intended for use in this study, but rather the survey afforded a convenient time to gather this information. Questions 15 through 19 ask students their opinions on word problems. For the purposes of this study and for clarification to the students participating in the study, a word problem was defined to be "A problem that requires you to analyze and synthesize rather than just recognize and plug in a number."

Questions 19 through 23 ask students about their levels of confidence when approaching and solving word problems. Questions 24 and 25 ask students about student beliefs on having the wrong answer versus leaving the question blank. Question 26 asks a student to rank, in order of importance, the components to successfully solving a problem. Question 27 is only located in

the post-semester questionnaire and asks students how they feel about their problem solving abilities now that the classroom experience is complete.

Students participating in the pre-semester questionnaire for questions 1 and 2 (See Tables 7 and 8) each responded with three resources they utilized outside the classroom. However, most students participating in the post-semester question only provided one or two resources they utilized inside and outside the classroom. The reason for this difference in answering methods from the pre-semester and post-semester questionnaires by the students is unclear.

Table 7: Question 1 Survey Responses

Question 1: When I attempt to solve an unfamiliar math problem OUTSIDE the classroom, I use these resources to help me successfully complete the problem: (Select up to 3)		
	Pre- Semester Percentages	Post-Semester Percentages
No Response	1.12%	0
Internet search: Google, Wikipedia, Yahoo!, etc.	25.09%	72.62%
Internet Math help site: (examples: Khan Academy, YayMath, etc)	3.75%	1.19%
iPhone or Android App	16.48%	13.10%
Textbook examples	8.24%	8.33%
Work with a classmate towards a solution	6.74%	1.19%
Class notes or worksheets	12.36%	2.38%
Previously worked practice problem	7.87%	0
Private or afterschool tutoring	2.62%	0
Family member or guardian	14.61%	0
I do not use resources to help me	0.75%	1.19%
Other: ____________________________ BE VERY SPECIFIC	0.37% (Calculator)	0

Table 8: Question 2 Survey Responses

Question 2: When I attempt to solve an unfamiliar math problem INSIDE the classroom, I use the following resources to help me successfully complete the problem: (Select up to 3)		
	Pre-Semester Percentages	Post-Semester Percentages
No Response	1.50%	9.52%
Textbook examples	16.85%	22.62%
Work with a classmate towards a solution	18.73%	45.24%
Notes from class	25.09%	19.05%
Find a similar problem from previously worked practice problems	20.60%	8.33%
Copy a classmate's work and turn it in as my own	4.49%	29.76%
Leave the problem blank and move on	11.61%	26.19%
I do not use resources to help me	1.12%	39.29%
Other:_____________________________ BE VERY SPECIFIC	0	0

Questions 3 and 4 are directly related to the student's willingness to persevere through a difficult mathematical problem (Tables 9 and 10). Time constraints and academic performance on a formal assessment are two examples of distractors students must overcome in a testing environment. These distractors are not evident at the same levels when completing homework assignments. It was hypothesized by this researcher that a student's willingness to dedicate the time necessary to solve a problem may be effected whether they are in a testing or homework situation. Both Question 3 and Question 4 had 89 students responding in pre-semester and 84 students responding post semester.

Table 9: Question 3 Survey Response

Question 3: On a test, how much time are you willing to spend on a math problem before you give up?		
	Pre-Semester Percentages	Post-Semester Percentages
No Response	0	0
3 minutes or less	17.98%	20.24%
4-6 minutes	46.07%	42.86%
7-10 minutes	22.47%	26.19%
11-20 minutes	10.11%	7.14%
More than 20 minutes	3.37%	3.57%

Table 10: Question 4 Survey Response

Question 4: On your homework or practice problems, how much time are you willing to spend on a math problem before you give up?		
	Pre-Semester Percentages	Post-Semester Percentages
No Response	0	0
3 minutes or less	16.85%	32.14%
4-6 minutes	49.44%	25.00%
7-10 minutes	11.24%	29.76%
11-20 minutes	11.24%	7.14%
More than 20 minutes	11.24%	5.95%

Question 5 shown in Table 11 attempts to narrow the reasons why a student would leave a question on a test blank rather than attempting a solution. The six answer options given to the students were selected from not only my own experience as a classroom teacher, but from input from colleagues. Question 5 had 89 students responding in pre-semester and 84 students responding post semester.

Table 11: Question 5 Survey Response

Question 5: When I leave a question blank on a math test, it is usually because… (Select One)		
	Pre-Semester Percentages	Post-Semester Percentages
No Response	0	0
The work required to solve the question is greater than the points possible for me to earn.	4.49%	8.33%
I'm not going to get it completely right anyways, so why bother?	10.11%	16.67%
I have no idea what the problem is looking for in an answer.	35.96%	33.33%
I have little or no confidence in my problem solving abilities.	12.36%	17.86%
I do not have enough time to answer the question.	11.24%	5.95%
The problem looks unfamiliar to me.	20.22%	11.90%
I have not worked a problem like this before.	5.62%	5.95%

Questions 15 through 18 address student beliefs and attitudes with regard to word problems. Students were given the options of responding with "Yes" or "No" to each question. Results for questions 15-18 are shown in Table 12.

Table 12: Questions 15 through 18 Survey Results

Survey Question	Pre-Semester "Yes" Percentage	Post-Semester "Yes" Percentage
Question 15: Word problems are difficult for me to understand	46.07%	52.38%
Question 16: Word problems are difficult for me to solve	40.45%	60.71%
Question 17: Word problems have little application in my everyday life	62.92%	46.43%
Question 18: I solve word problems in my everyday life	34.52%	48.31%

The reasons for student resistance to solving word problems were investigated in Question 19. Students were allowed to pick one of the six selections to explain their dislike of word problems. Survey results are shown below in Table 13.

Table 13: Question 19 Survey Response

Question 19: The primary reason I do not like word problems is: (Select One)		
	Pre-Semester Percentages	Post-Semester Percentages
Not Answered	0	0
Too much time	17.98%	18.29%
Too much work	17.98%	14.63%
"Lost" in process	41.57%	40.24%
Difficulty understanding	15.73%	21.95%
Does not appear familiar	2.25%	0
Student prefers word problems	4.49%	4.88%

Questions 20-23 continue the “word problem” theme by questioning student confidence levels in differing stages of the problem solving process. Students were asked to answer “Yes” or “No” to each question, and the results are shown in Table 14.

Table 14: Questions 20-23 Survey Response

Survey Question	Pre-Semester "Yes" Percentage	Post-Semester "Yes" Percentage
Question 20: When solving unfamiliar problems, I tend to examine the facts given to me in the problem	73.03%	70.24%
Question 21: When solving unfamiliar math problems, I feel confident I can figure out what the problem is asking me to find.	44.94%	52.38%
Question 22: When solving unfamiliar math problems, I feel confident that I can build a connection between the facts given in the problem and the solution they are asking me to find	50.56%	55.95%
Question 23: When solving unfamiliar math problems, I give up trying when I feel uncomfortable	55.06%	61.90%

Question 27 appears only on the post-semester questionnaire as it was a designed to demonstrate whether students believed their experiences in the course had effected their problem solving skills. The results of the survey are shown in Table 15.

Table 15: Question 27 Survey Response

Question 27: Since your experience in this class with solving problems, how do you feel your problem solving ability has changed?	Post-Semester Percentage
I feel more confident in my ability to solve difficult mathematical problems	48.81%
I feel about the same level of confidence in my ability to solve difficult mathematical problems	36.90%
I feel less confident in my ability to solve difficult mathematical problems	14.29%

5.5 Direct Observations

As previously mentioned in the observations from the selected activities, students utilized the wipe-off boards as a means of communicating ideas to other students. In my role as a classroom teacher, I observed multiple instances of students pointing to the work they had done on their board while engaged in a peer discussion regarding the problem. Similar mathematical dialogue amongst class members became commonplace within the classroom. Students who were unwilling to share their ideas in front of the class were willing to share with their table or group members in the more intimate setting. I observed a sense of pride develop in their solutions as they shared with other students.

The impact of the boards as an organizer for problem solving was evidenced while monitoring students in state-mandated testing. As a classroom teacher, I am required to monitor students to ensure minimal disruption and maximum security of the testing environment and materials. In this setting, students were allowed to have only the state-prescribed documents consisting of a formula sheet, a typing help sheet, and a sheet of graph paper that could be used as scratch paper. They were not allowed to have the wipe-off boards or the paper templates in the vicinity of the testing room. Several times during my monitoring of the testing room, I noticed students creating a simple foursquare pattern of two perpendicular lines on their scratch sheet and writing notes, diagrams, and formulae.

In classroom exercises, work done on the problem solving board served as an indicator to the teacher of what concepts were being grasped and by whom. As the classroom teacher, I was able to monitor student progress by taking a quick glance at the work on the boards and address any issues that I noticed. The boards also gave me a great source for higher order questioning during my communications with individual students and groups alike. From the board content, I

could ask how an idea related to the topic and how they intended to apply it without needing to watch every step made in their solution. When asked questions about the work shown on the board, students would point to the item I was questioning and use either their fingers or their marker to draw connections to the other ideas on the board while verbally explaining their relationship and application to the problem.

CHAPTER 6: DISCUSSION AND FINDINGS

As stated previously, the instrument of change that was originally presented to students, the Engineering Problem Solving Method, failed to be accepted by the students as a tool for problem solving. The discussion of data and findings in this chapter reflect the data gathered using the graphic organizer.

6.1 Use of the Graphic Organizer

The number of students using the graphic organizer declined over the duration of the semester in both the classroom and for homework. The graphs shown in Figures 2 and 3 illustrate this result. Figure 2 shows spikes in student use at Week 9 and Week 14. The surge in graphic organizer use shown in Figure 2 corresponds to the midterm examination in week 9 and the End of Course examination that took place around weeks 13 and 14. Figure 3 also shows a surge in home use of the graphic organizer from week 5 to week 10 of instruction. Curriculum contained within these weeks consisted of similarity, ratio and proportion, congruence, and proofs with extensive home assignments to cover the material.

6.2 Documentary Evidence

Students utilized the boards throughout the semester on an “as needed” basis, determined by the students. In the Peanut Butter and Jelly exercise, students found the task easy and did not use the boards at all. Students participating in the Perplexed by Pizza exercise utilized the boards to collect formulas, draw out their diagrams to illustrate the areas of the pizza, and subsequently, to slice those pizza diagrams to compare the areas of sectors in the final question. Students used the boards for general information like formulas and measurements, but chose to do the work for Perplexed by Pizza on their worksheet. It was not until they were faced with the challenge of Finding the Volume of an Irregular Object that students made continuous use of the

boards. The students used the organizers to track ideas for gathering the measurement information as well as planning and implementing their method for calculating the volume of the cup. As evidenced in the documentary data presented in the previous chapter, students involved in the Finding the Volume of an Irregular Object exercise were inventive in their problem solving approaches. Students played to their strengths and expressed their individuality in how they attacked the problem rather than relying on a prescribed “trick” to the solution.

6.3 End of Course and Survey Data

Student performance on the Geometry End of Course exams showed no marked difference in performance between the research population and the two high schools involved. As discussed in the previous chapter, the Mathematics and Problem Solving Survey was presented to students both pre and post semester to measure the effects of their experiences on their attitudes about math and problem solving. The results shown in Figure 11 show that student attitudes were not affected by their experiences in the class. These results are not surprising in that it has taken at least 14-15 years of educational experiences, family influences, and academic seat-time to form these attitudes within students. Their exposure and practice in a problem-solving method is limited to the 18-week duration of the course; a minute amount of time when compared to 14 years.

Students also participated in the Student Study-Behaviors and Problem Solving Attitudes survey discussed in the previous chapter. The data collected from this survey showed some interesting results regarding changes in resources used by students for problem solving inside and outside the classroom when comparing the pre-semester survey results to those received from the post-semester survey. Table 5 in the previous chapter shows that pre-semester 25.09% of students reported they used Internet searches like Google!™ and Yahoo!™ for math help

outside the classroom. This percentage surged to 72.62% in the post semester survey results. Resources used by students inside the classroom also changed according to the data shown in Table 6. Pre-semester results show that inside the classroom, 18.73% of students would work with a classmate toward a solution, 4.49% would copy a classmate's work and turn it in as their own, and 1.12% stated they did not use resources to help them. The post-semester results show that the percentage of students who would work with a classmate towards a solution increased to 45.24%, and the number of students who would copy a classmate's work and turn it in as their own increased to 29.76%. The students who reported not using resources inside the classroom also increased to 39.29%.

Students reported in Table 13 that 48.81% believed their confidence in their problem solving abilities had increased due their experience in the class. Of the students remaining in the survey, 36.90% reported there had been no change in their confidence level and 14.29% reported they felt less confident in their problem solving abilities.

6.4 Observations

In classroom observations in addition to the three selected assignments, students continued to use the boards to communicate their ideas to other students. Students were observed on multiple occasions and at problems of various complexity levels to use their boards as organizational tools. Watching a student point to their board and draw lines connecting ideas to form problem solving strategies, either by using their finger or a marker, while engaged in a discussion with other peers is an illustration of the increase in confidence students experienced through the use of the graphic organizer. The evidence of students creating the pattern of the graphic organizer on their scratch paper during standardized testing is a suggestion that the

organizational structure of the organizer had an influence on their personal problem solving schema, beyond the use of classroom communications.

As the classroom teacher, I continued to find the work on the board as an excellent source for diagnostic and higher order questioning material. The ideas and connections shown on the board allowed me to quickly diagnose whether a student had a firm grasp of the material, or whether they needed some assistance with their understanding. If a student appeared to have a solid understanding of the concept, I could probe the depth of their understanding with higher order questioning to analyze their application and synthesis of the material. Students that struggled with an idea were given the opportunity to receive the information from other students and from the student perspective rather than just from the lesson presented to the class. This exposure to varying methods of solutions and applications of ideas allowed the student to select the method which made the most sense to them, which I believe allowed for a better understanding of the concept as a whole.

CHAPTER 7: CONCLUSIONS AND FUTURE RESEARCH

7.1 Conclusions

In the findings of the previous chapter it was noted that the student use of the organizer generally declined as the semester continued. One of the characteristics of successful scaffolding is the decrease in reliance on the physical structure and external support mechanism with a greater reliance on the student's internalized mechanisms for moving newly acquired information into a personalized understanding of the material, as described by Van De Pol, Volman, and Beishuizen in the literature review. I believe that the decline in use of the graphic organizer shown in the data is an indication of the internalization by students of the structure provided by the organizer. As conformation of this, students were observed drawing the organizer pattern on their scratch paper during the Geometry End of Course exam.

The increase in student confidence shown in the survey is also evidenced in the exploratory approach that students took in the Finding the Volume of an Irregular Object assignment. Students who lack confidence in their problem solving abilities will not attempt such adventurous means of solution, (as noted by Lubienski, Carr, and Steele in the previously cited research). The increase in willingness to work with others found in the survey along with the classroom sharing of ideas and strategies observed students used their boards serves as yet more evidence of the student's increase in confidence with problem solving.

As the teacher, the use of a tangible problem-solving template allowed me to quickly identify student misunderstandings of concepts, arithmetic errors, and improper applications of properties. The problem solving boards allowed me, as the instructor, to provide encouragement to a student who was struggling within the process by graphically illustrating to them the expanse of ideas and connections they had successfully completed while pointing out areas

where they may need to check their facts a bit closer. The use of a wipe-off board also underlined the principle that mistakes were not permanent and could be easily fixed before they became problematic or a source of embarrassment. While this was a positive aspect of using the wipe off boards for students, it made the collection of student sample work on the boards difficult. In retrospect, I would suggest the use of a paper template for students to use and turn in with their assignments for the sole purpose of data collection, at least for the first few times an instructor implements the problem solving method.

In my classroom, I will continue the use of the graphic organizer as part of my method of teaching Geometry and the problem solving skills the course requires. The structure provided by the organizer was instrumental in the development of the problem solving skills acquired by my students, and the subsequent success they experienced in their problem solving was the foundation to their increase in confidence. I have found that the boards served a double duty to both the student and the teacher. The graphic organizer served as a diagnostic tool for both the teacher and for student self-monitoring of progress in addition to serving as a means of peer and student-teacher communications.

7.2 Where to go from here

Use of the graphic organizer by students was shown within the data to vary with the complexity of the task at hand. We saw that the use of the boards was non-existent during the Peanut Butter and Jelly sandwich exercise, which required minimal application of newly acquired information, but the use of the boards was extensive and multi-faceted when students attempted to solve the Finding the Volume of Irregular Object problem that required extensive use of problem-specific information. This suggests a possible hypothesis for further research: Is the graphic organizer more useful and used more often when the problem demands more short-

term memory work and has less support from long term memory? A future researcher could structure an experimental series consisting of 7-10 assignments which require increasing degrees of short term memory work coupled with a decreasing long-term memory element. By tracking the use of the graphic organizer throughout the assignments, one could surmise the role of the organizer in the problem solving schema of the students.

Problem solving skills are fundamentally required for success in life. These skills do not suddenly appear, but are fostered and propagated through trial and practice. The exercises to develop these skills should be introduced at an early stage in a student's academic career and practiced continuously in order to further their problem solving development. Many students had never been introduced to a formal mode of problem solving in the durations of their mathematics classes. For the majority of students, problem solving had been done by teacher example of a specific problem type and then the students were expected to duplicate the methodology shown to solve their problem.

I believe that if students were given the foundation of a problem solving method in a much earlier mathematics class, they would be much more resilient in their problem solving endeavors. It would be interesting to compare the problem-solving resiliency in a longitudinal study of a student who practices the use of the graphic organizer prescribed in this research from the sixth through twelfth grades as compared to the students who were only exposed to the organizer in one eighteen week class.

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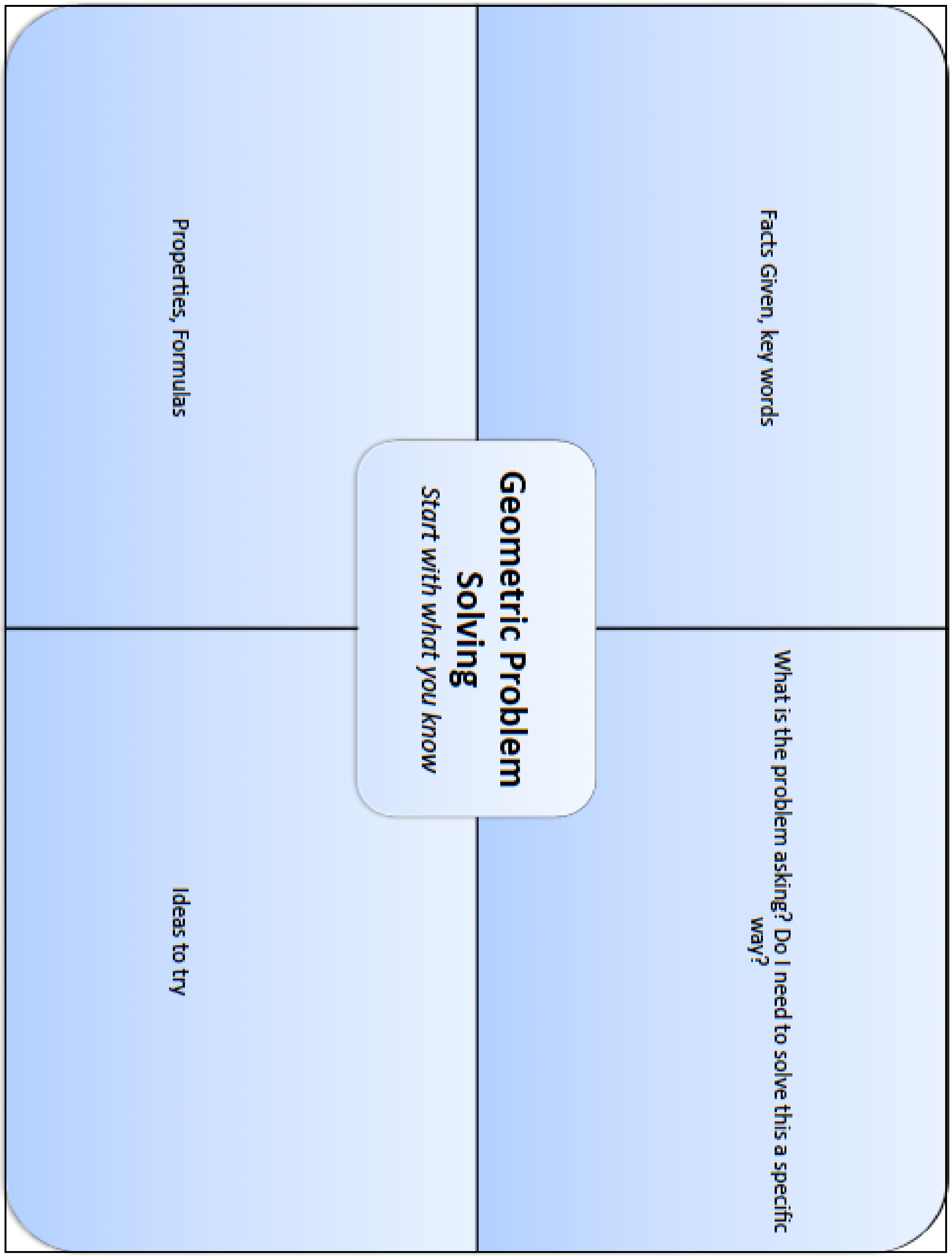
APPENDIX A: THE ENGINEERING PROBLEM SOLVING METHOD AND MATH

1. State what you are trying to accomplish.
    a. What is the problem you are trying to solve?
    b. What are the requirements and restraints under which this problem must be solved?
        i. In Engineering, constraints and requirements could be size, prescribed use, environment, materials used, or cost.
        ii. In Mathematics, constraints and requirements applies to methods used to solve the problem, formulae, calculator usage allowed, and required means of answer presentation.
2. What do you know and what do you need to know?
    a. Student assimilation of knowledge gained up to this point and how it applies to the problem they are faced with solving.
    b. Student analysis of what information needs to be gained and researched in order to solve the problem.
3. Formulate a plan of attack.
    a. Student analysis of information known and gained and how to implement this to solve the problem.
        i. Steps 2 and 3 are generally repeated several times before a methodology is decided upon.
        ii. Experimentation in solving methods
4. Implementation of their plan
    a. Student implementation of their plan using their knowledge of the problem and assimilation of information gained and given.
5. Evaluate your results.
    a. Student self-evaluation of their results and critique
6. Draw conclusions based on your solution
    a. Student assessment of their results
    b. Student analysis of their progress throughout the process

    Student revises their approaches to steps 2-4 as necessary in order to refine and deepen their understanding of the content and correct any errors in process.

APPENDIX B: GEOMETRIC PROBLEM SOLVING TEMPLATE



APPENDIX C: PEANUT BUTTER AND JELLY

Objective: Students will write clear and concise directions to complete a common task. By demonstrating the necessity for attention to detail along with clear and concise language, students will then review and revise their instructions to reflect the level of detail and step-by-step instruction required to accurately journalize their learning and reflections. This process develops an understanding of the attention to detail and process necessary to communicate in Mathematics, as well as encouraging the student to use self and peer reflection to improve and analyze strengths and weaknesses present in their work or cognitive processes. Students will then create a flowchart showing the process.

Materials needed:

Student -	Student's Engineering notebook	Pen for writing
Teacher -	1 jar of peanut butter	1 jar of jelly
	1 loaf of bread	1 butter knife
	1 roll of paper towels (for cleaning)	1 spray cleaner

LA GLE's Addressed:
Grade 9 - Follow and interpret processes expressed in flowcharts
Grade 10 - Develop formal and informal proofs

Process:
Instruct students to individually write in their engineering notebook instructions on how to build a peanut butter and jelly sandwich using the following supplies (show them to the students as you list them):

1 jar of peanut butter	1 jar of jelly
1 loaf of bread	1 butter knife

Allow 5-7 minutes for students to write their "directions". Upon completion, ask for a volunteer to share their directions. After reading over the student's work, teacher will physically demonstrate the process following the student's instructions to the letter! It is imperative that the teacher not "assume" a single step. For instance, if the student's instructions read "Put peanut butter on the bread" the teacher should take the unopened jar of peanut butter and place it directly on the unopened loaf of bread. Continue the process until you have completed the student's instructions. This should facilitate a conversation as to the level of detail and communication necessary to complete. Teacher should write down "bullet point ideas" offered by students on the board or other highly visible area.

Students will journalize these bullet points and a self critique of their instructions. (10-15 minutes). Students may work with each other to develop their critique. Students will then re-

write their instructions using the new bullet point ideas and with a clear understanding of the expectations for journalizing (10-15 minutes).

Students, in groups of 3-4, will construct a flowchart showing the processes for creating a peanut butter and jelly sandwich. They will then present their chart to the class while providing justification for the choices they made.

Engineering Connections:
Journaling, Process diagrams and flowcharts, attention to detail, engineering and lab notebook process

Mathematics Connections:
Problem solving, decision making, justification of work shown, showing all your work

Possible Lesson Extensions and variations:
Have students construct a flowchart demonstrating the problem solving process
Have students construct a flowchart demonstrating the process for solving a specific mathematical problem
Have students construct a two-column proof of how to solve an algebraic equation, showing correlation between statement and reason.
Have students construct a flowchart showing the problem solving process in Geometry.
Have students construct a two-column proof showing the solution to a geometric problem

APPENDIX D: PERPLEXED BY PIZZA

Perplexed By Pizza

Josea calls Domino’s to order a pizza. She orders a 16” large pepperoni for $12.00. Thad, the Domino’s employee, informs Josea that they are out of 16” pizzas, but she could order 2 8” pizzas at $6.00 each and it would be the same thing. Josea does not agree with Thad. Do you?

1. Who do you believe? Thad _______ Josea_______

2. Prove your answer:

3. The 8” pizza is cut into 12 slices and the 16” pizza is cut into 8 slices. Which choice would give you the most food for your money? Explain your reasoning.

APPENDIX E: VOLUME OF AN IRREGULAR SHAPE – PLASTIC CUP

Supplies needed per team:

Centimeter Ruler, Cup, Protractor, Calculator, and Lab Sheets

Objective: Students will use their knowledge of the volume of polyhedra to find the volume of an object that requires formula development and algebraic manipulation.

Step 1 – Initial Diagram

Label all measurements in the appropriate locations in centimeters to the nearest tenth. (10 points) - Both radii, slant height, height of the cup, and the angle made with the lip of the cup and the largest opening

Step 2 - *Be sure to answer each question using complete sentences and to answer all parts of the question.*

A) In your opinion, which polyhedral shape does this cup resemble? (Prism, pyramid, cylinder, cone, or sphere) (5 points)

B) What properties in the shape of the cup remind you of your polyhedral shape? (10 points)

C) What is the volume formula for your similar shape? (5 points)

D) What properties in the shape of the cup are different from your selected polyhedral shape? (10 points)

E) Describe which modifications need to be made to the polyhedral volume formula, which would allow you to accurately calculate the volume of the cup? (Hint: Additions of volume, subtractions of volume, etc.) (10 Points)

Step 3 – Volume Worksheet (20 points)

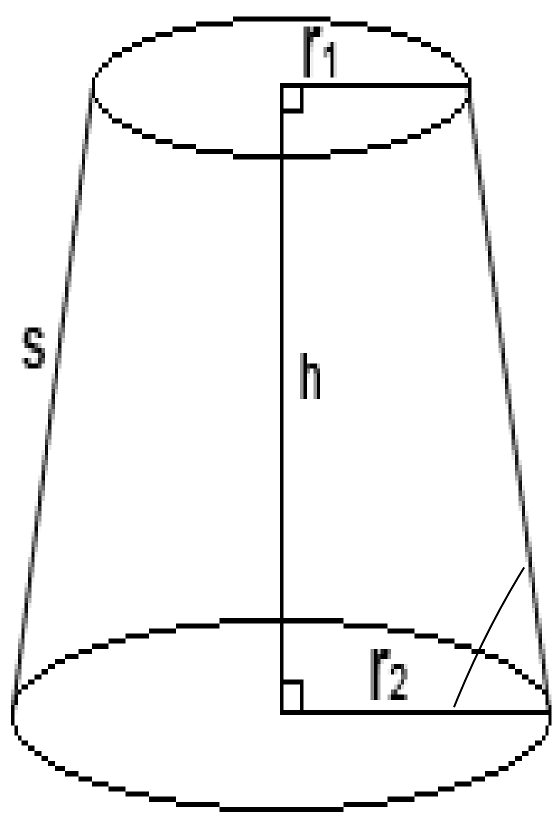
Use the cup diagram on the VOLUME WORKSHEET

a) Use the Volume worksheet to show your modifications and estimations used to calculate the volume.
b) Use the VOLUME WORKSHEET to show all algebraic work and volume calculations. Be sure to label ALL calculations. Do not forget the units!

INITIAL DIAGRAM

Label all measurements in the appropriate locations in centimeters to the nearest tenth. (10 points) - Both radii, slant height, height of the cup, and the angle between the lip of the cup and the largest opening.

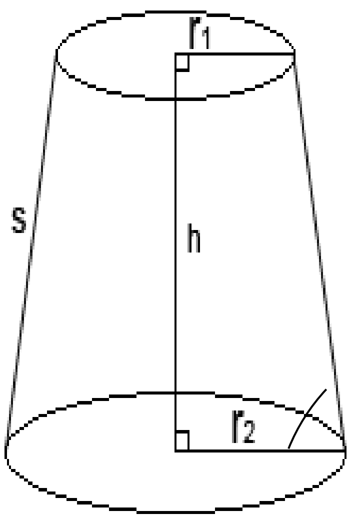
THE DIAGRAM BELOW IS NOT TO SCALE! Measure your cup NOT the diagram!



Volume Worksheet

a) Use this worksheet to show your modifications and estimations used to calculate the volume.
b) Use the VOLUME WORKSHEET to show all algebraic work and volume calculations. Be sure to label ALL calculations. Do not forget the units!

DIAGRAM BELOW IS NOT TO SCALE! Measure your cup NOT the diagram!



Calculated volume of the cup is:______________________________________

APPENDIX F: MATHEMATICS AND PROBLEM SOLVING SURVEY

Mathematics and Problem Solving

7. I can solve time-consuming problems.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

8. There are word problems that cannot be solved using simple, step-by-step procedures.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

9. Understanding concepts is important in mathematics.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

10. Word problems are important in mathematics.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

11. Effort can increase mathematical ability.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

12. Mathematics is used in my daily life.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

Post-Semester Student Questionnaire
Mathematics and Problem Solving

1. I can solve time-consuming problems.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

2. There are word problems that cannot be solved using simple, step-by-step procedures.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

3. Understanding concepts is important in mathematics.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

4. Word problems are important in mathematics.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

5. Effort can increase mathematical ability.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

6. Mathematics is used in my daily life.
    - Totally Agree
    - Agree
    - Neither Agree or Disagree
    - Disagree
    - Totally Disagree

APPENDIX G: PRE-SEMESTER STUDENT BEHAVIORS QUESTIONNAIRE

Student Study Behaviors and Problem Solving Attitudes
Pre-semester
Be honest and Factual

1. When I attempt to solve an unfamiliar math problem OUTSIDE the classroom, I use these resources to help me successfully complete the problem:
   Select up to 3 resources
   A. Internet search: Google, Wikipedia, Yahoo!, etc.
   B. Internet Math help site: (examples: Khan Academy, YayMath, etc)
   C. iPhone or Android App
   D. Textbook examples
   E. Work with a classmate towards a solution
   F. Class notes or worksheets
   G. Previously worked practice problem
   H. Private or afterschool tutoring
   I. Family member or guardian
   J. I do not use resources to help me
   K. Other: ___________________________ BE VERY SPECIFIC

2. When I attempt to solve an unfamiliar math problem INSIDE the classroom, I use the following resources to help me successfully complete the problem:
   Select up to 3 resources
   A. Textbook examples
   B. Work with a classmate towards a solution
   C. Notes from class
   D. Find a similar problem from previously worked practice problems
   E. Copy a classmate's work and turn it in as my own
   F. Leave the problem blank and move on
   G. I do not use resources to help me
   H. Other:___________________________ BE VERY SPECIFIC

3. On a test, how much time are you willing to spend on a math problem before you give up? (Select One)
   A. 3 minutes or less
   B. 4-6 minutes
   C. 7-10 minutes
   D. 11-20 minutes
   E. More than 20 minutes

4. On your homework or practice problems, how much time are you willing to spend on a math problem before you give up? (Select One)
   A. 3 minutes or less
   B. 4-6 minutes
   C. 7-10 minutes
   D. 11-20 minutes
   E. More than 20 minutes

5. When I leave a question blank on a math test, it is usually because… (Select One)
   A. The work required to solve the question is greater than the points possible for me to earn.
   B. I'm not going to get it completely right anyways, so why bother?
   C. I have no idea what the problem is looking for in an answer.
   D. I have little or no confidence in my problem solving abilities.

E. I do not have enough time to answer the question.
F. The problem looks unfamiliar to me.
G. I have not worked a problem like this before.

6. When studying for a test, I tend to rework homework problems.
   A. Yes
   B. No

7. When studying for a test, I tend to rework class examples.
   A. Yes
   B. No

8. When studying for a test, I create my own practice problems by changing the values in previously reviewed problems.
   A. Yes
   B. No

9. When studying for a test, I make flashcards to memorize the required vocabulary.
   A. Yes
   B. No

10. When studying for a test, I review the daily objectives to make sure I can complete each one.
    A. Yes
    B. No

11. When studying for a test, I work with a private or school tutor to clarify concepts and procedures.
    A. Yes
    B. No

12. When studying for a test, I participate in peer study groups.
    A. Yes
    B. No

13. When studying for a test, I work with a parent, guardian, or family member for assistance.
    A. Yes
    B. No

14. When studying for a test, I make no effort to review or study.
    A. Yes
    B. No

15. Word problems are difficult for me to understand.
    A. Yes
    B. No

16. Word problems are difficult for me solve.
    A. Yes
    B. No
17. Word problems have little application to my everyday life.
    A. Yes
    B. No
18. I solve word problems in my everyday life.
    A. Yes
    B. No
19. The primary reason I do not like word problems is: (Select One)
    A. They take too much time
    B. They take too much work
    C. I get "lost" in the process of solving it

D. I have trouble understanding the question
E. The words do not look familiar to me
F. I prefer word problems

20. When solving unfamiliar math problems I tend to examine the facts given to me in the problem.
    A. Yes
    B. No

21. When solving unfamiliar math problems, I feel confident I can figure out what the problem is asking me to find.
    A. Yes
    B. No

22. When solving unfamiliar math problems, I feel confident that can build a connection between the facts given in the problem and the solution they are asking me to find.
    A. Yes
    B. No

23. When solving unfamiliar math problems, I give up trying when I feel uncomfortable
    A. Yes
    B. No

24. Having a wrong answer is just as bad as having no answer.
    A. Yes
    B. No

25. Leaving a problem blank is better than leaving a problem incomplete
    A. Yes
    B. No

26. Rank the following in order of importance for successful completion of a mathematics problem:
    (1 is the most important, 6 is the least important)

A. ____Personal commitment to finding a solution to the problem.

B. ____Confidence in your personal mathematical ability and knowledge.

C. ____Confidence that you're taking the correct steps towards completion.

D. ____ Understanding what the facts given to you by the problem.

E. ____ Understanding what the question is asking you to find.

F. ____Your answer must always be "right".

APPENDIX H: POST-SEMESTER STUDENT BEHAVIORS QUESTIONNAIRE

Student Study Behaviors and Problem Solving Attitudes Postsemester – Be honest and Factual

1. When I attempt to solve an unfamiliar math problem OUTSIDE the classroom, I use these resources to help me successfully complete the problem:
   Select up to 3 resources
   A. Internet search: Google, Wikipedia, Yahoo!, etc.
   B. Internet Math help site: (examples: Khan Academy, YayMath, etc)
   C. iPhone or Android App
   D. Textbook examples
   E. Work with a classmate towards a solution
   F. Class notes or worksheets
   G. Previously worked practice problem
   H. Private or afterschool tutoring
   I. Family member or guardian
   J. I do not use resources to help me
   K. Other: ___________________________ BE VERY SPECIFIC

2. When I attempt to solve an unfamiliar math problem INSIDE the classroom, I use the following resources to help me successfully complete the problem:
   Select up to 3 resources
   A. Textbook examples
   B. Work with a classmate towards a solution
   C. Notes from class
   D. Find a similar problem from previously worked practice problems
   E. Copy a classmate's work and turn it in as my own
   F. Leave the problem blank and move on
   G. I do not use resources to help me
   H. Other:____________________________ BE VERY SPECIFIC

3. On a test, how much time are you willing to spend on a math problem before you give up? (Select One)
   A. 3 minutes or less
   B. 4-6 minutes
   C. 7-10 minutes
   D. 11-20 minutes
   E. More than 20 minutes

4. On your homework or practice problems, how much time are you willing to spend on a math problem before you give up? (Select One)
   A. 3 minutes or less
   B. 4-6 minutes
   C. 7-10 minutes
   D. 11-20 minutes
   E. More than 20 minutes

5. When I leave a question blank on a math test, it is usually because… (Select One)
   A. The work required to solve the question is greater than the points possible for me to earn.
   B. I'm not going to get it completely right anyways, so why bother?
   C. I have no idea what the problem is looking for in an answer.
   D. I have little or no confidence in my problem solving abilities.
   E. I do not have enough time to answer the question.
   F. The problem looks unfamiliar to me.
   G. I have not worked a problem like this before.

6. When studying for a test, I tend to rework homework problems.
    A. Yes
    B. No

7. When studying for a test, I tend to rework class examples.
    A. Yes
    B. No

8. When studying for a test, I create my own practice problems by changing the values in previously reviewed problems.
    A. Yes
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9. When studying for a test, I make flashcards to memorize the required vocabulary.
    A. Yes
    B. No

10. When studying for a test, I review the daily objectives to make sure I can complete each one.
    A. Yes
    B. No

11. When studying for a test, I work with a private or school tutor to clarify concepts and procedures.
    A. Yes
    B. No

12. When studying for a test, I participate in peer study groups.
    A. Yes
    B. No

13. When studying for a test, I work with a parent, guardian, or family member for assistance.
    A. Yes
    B. No

14. When studying for a test, I make no effort to review or study.
    A. Yes
    B. No

15. Word problems are difficult for me to understand.
    A. Yes
    B. No

16. Word problems are difficult for me solve.
    A. Yes
    B. No

17. Word problems have little application to my everyday life.
    A. Yes
    B. No

18. I solve word problems in my everyday life.
    A. Yes
    B. No

19. The primary reason I do not like word problems is: (Select One)
    A. They take too much time
    B. They take too much work
    C. I get "lost" in the process of solving it
    D. I have trouble understanding the question
    E. The words do not look familiar to me
    F. I prefer word problems

20. When solving unfamiliar math problems I tend to examine the facts given to me in the problem.
    A. Yes
    B. No

21. When solving unfamiliar math problems, I feel confident I can figure out what the problem is asking me to find.
    A. Yes
    B. No

22. When solving unfamiliar math problems, I feel confident that can build a connection between the facts given in the problem and the solution they are asking me to find.
    A. Yes
    B. No

23. When solving unfamiliar math problems, I give up trying when I feel uncomfortable
    A. Yes
    B. No

24. Having a wrong answer is just as bad as having no answer.
    A. Yes
    B. No

25. Leaving a problem blank is better than leaving a problem incomplete
    A. Yes
    B. No

26. Rank the following in order of importance for successful completion of a mathematics problem:
    (1 is the most important, 6 is the least important)
    A. ____Personal commitment to finding a solution to the problem.
    B. ____Confidence in your personal mathematical ability and knowledge.
    C. ____Confidence that you're taking the correct steps towards completion.
    D. ____ Understanding what the facts given to you by the problem.
    E. ____ Understanding what the question is asking you to find.
    F. ____Your answer must always be "right".

27. Since your experience in this class with solving problems, how do you feel your problem solving ability has changed?
    A. I feel more confident in my ability to solve difficult mathematical problems
    B. I feel about the same level of confidence in my ability to solve difficult mathematical problems
    C. I feel less confident in my ability to solve difficult mathematical problems

APPENDIX I: INSTITUTIONAL REVIEW BOARD DOCUMENTS

Application for Exemption from Institutional Oversight

LSU

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://www.lsu.edu/screeningmembers.shtml

- A Complete Application Includes All of the Following:
  - **(A)** Two copies of this completed form and two copies of part B thru E.
  - **(B)** A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
  - **(C)** Copies of all instruments to be used.
    - *If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
  - **(D)** The consent form that you will use in the study (see part 3 for more information.)
  - **(E)** Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtaining.com/users/login.php.)
  - **(F)** IRB Security of Data Agreement: (http://www.lsu.edu/irb/IRB%20Security%20of%20Data.pdf)

1) Principal Investigator: Angelique Treadway **Rank:** Grad Student

Dept: Masters of Natural Sciences **Ph:** (337) 288-3193 **E-mail:** atread4@tigers.lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each

Dr. Todd ~~Moore~~ Monroe, Professor, Biological Engineering, (225) 803-2068, tmonroe@lsu.edu

Dr. James Madden, Professor, Mathematics, (225) 978-3525 madden@math.lsu.edu

IRB# E5574 LSU Proposal # ______

(✓) Complete Application

(✓) Human Subjects Training

3) Project Title: Using Active Microfluidics Research to Increase Strategic Knowledge Application in High School Geometry

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 7-29-2014

4) Proposal? (yes or no) NO **If Yes, LSU Proposal Number** ______

Also, if YES, either

○ **This application completely matches the scope of work in the grant**

OR

○ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) Geometry students

*Circle any **"vulnerable populations" to be used:** (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature ______ **Date** 6/30/11 (no per signatures)

** **I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ✓ Not Exempted ____ Category/Paragraph 1

Reviewer Mathews **Signature** Robt C Mathews **Date** 7/30/11

Parental Permission Form

Project Title: Using Active Microfluidics Research to Increase Strategic Knowledge Application in High School Geometry

Performance Site: Northside High School, Lafayette, Louisiana

Investigator: The following investigator is available for questions, M-F, 7:00 a.m.-3:00 p.m. Angie Treadway (337) 521-7000, or by appointment.

Purpose of the Study: To test the effects of real-world application problems on a student's ability to use tools and knowledge strategically as described in the Common Core State Standards while enrolled in a sophomore Geometry class.

Exclusion Criteria: Students who are not enrolled in Mrs. Angie Treadway's Geometry or Honor's Geometry class.

Description of the Study: The effectiveness of these measures to increase a student's ability to use knowledge gained effectively and strategically in high school Geometry will be measured through both formative (informational) and summative (for a grade) assessments for the duration of the semester. Student assessment begins with a pre-course test that evaluates student problem solving skills, self-analysis, and beliefs. Content exams will be administered in a semi-bi-weekly basis and evaluated for student understanding and application of concepts taught. Lat reports and reflections are done several times in the course of study for the bi weekly exam, and will serve as further evaluation of student understanding and application of knowledge gained. Students will complete a post-course test assessing the student's development of problem solving skills, changes in self-analysis, and beliefs. Student reflections, lab notebook writings, quality of design and presentation of the micromixing device, End of Course testing results, and journaling the observational analysis of student growth will also serve as assessment for the effectiveness of this program. Students who will not participate in the research are required to complete the same assignments as those who are participating in the research.

Right to Refuse: Participation is voluntary, and a child will become part of the study only if both child and parent agree to the child's participation. At any time, either the subject may withdraw from the study or the subject's parent may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

Privacy: Investigators may review the school records of participants in this study. Results of the study may be published, but no names or identifying information will be included for publication. Subject identity will remain confidential unless law requires disclosure. Samples of student work may be submitted as part of the publication, but will be done so anonymously.

Financial Information: There is no cost for participation in the study, nor is there any compensation to the subjects for participation.

Signatures: The study has been discussed with me and all my questions have been answered. may direct additional questions regarding study specifics to the investigator. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutiona Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I will allow my child to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Parent's Signature:________________________________ Date:____________________

The parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent from to the parent/guardian and explained that by completing the signature line above he/she has given permission for the child to participate in the study.

Signature of Reader:________________________________ Date:____________________

:tudy Exempted By:
r. Robert C. Mathews, Chairman
nstitutional Review Board
ouisiana State University
03 B-1 David Boyd Hall
25-578-8692 | www.lsu.edu/irb
xemption Expires: 7/29/2014

Student Assent Form

I,______________________________, agree to be in a study to help Geometry students to become better problem solvers. I understand that the work I submit may be included anonymously in the study and possible publication of study results. I understand that I must complete the same homework, assignments, classwork, and projects required by the instructor whether I decide to participate in the study or not. I can decide to stop being in the study at any time without getting in trouble.

Student Signature:__________________________ Age:_____ Date:____________

Witness* ______________________________ Date:_______________ *

(N.B. Witness must be present for the assent process, not just the signature by the minor.)

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 7-29-2014

VITA

Angelique Treadway Duncker is a cum laude graduate of the University of Louisiana at Lafayette in Secondary Education Mathematics and a degree candidate at Louisiana State University, Baton Rouge, for a Master's in Natural Sciences – Mathematics. Expected thesis submission date is July 1, 2013. Angelique has been teaching high school mathematics since 2008 beginning at Breaux Bridge High School in Breaux Bridge, Louisiana, and currently teaching at Northside High School in Lafayette, Louisiana. While certified to teach all high school mathematics courses, including a certification for Advanced Placement Calculus AB, she specializes in teaching Geometry.

During her teaching career she has been named Teacher of the Year for 2012-2013 by both Breaux Bridge High School and the St. Martin Parish School District. She has also developed several means of incorporating technology into classroom routines, lessons, and activities for presentation to other education professionals at the min-LaCUE held in Crowley, Louisiana in 2010, and for presentation through the St. Martin Parish School District Technology Education department. As of the writing of this thesis, she is currently developing a comprehensive curriculum for Lafayette Parish School System in conjunction with the Teacher Leader Cadre in order to implement Common Core State Standards into the 2013-2014 High School Geometry curriculums.

Angelique aspires to go into full-time curriculum development and coordination to continue educating both students and educators alike, and to continue developing relevant, intriguing, and challenging curriculum for the classroom teacher.