# Using writing assignments in high school geometry to improve students' proof writing ability

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# USING WRITING ASSIGNMENTS IN HIGH SCHOOL GEOMETRY TO IMPROVE STUDENTS' PROOF WRITING ABILITY

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# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## ABSTRACT

The Common Core State Standards encourage the use of writing in mathematics classrooms. This study was designed to create a template for high school teachers to use in a geometry class to improve students' proof writing ability. The students enrolled in the class were asked to complete journal and expository writing assignments throughout the course. The assignments were scored with a rubric. To assess if growth was made in proof writing, the students were all given a test four times throughout the school year. All four tests were assessed using the same rubric. We provide evidence that the template was successful in increasing the students' ability to write geometric proofs by increasing their use of mathematical vocabulary, increasing their ability to use the information in a problem, and increasing their ability to justify their steps with correct mathematical facts or theorems.

# CHAPTER 1. INTRODUCTION

Writing is an integral part of classes such as English and history, but is often left out of many mathematics courses. This may be due to numerous factors, including curriculum design and teachers' personal preferences. However, it should be an integral part of all students' mathematical education. Writing is a part of the curriculum that the National Council of Teachers of Mathematics (NCTM) developed and is also part of the new Common Core State Standards. "NCTM suggests that students write explanations about how they solved a problem, solutions to exercises as if they were writing a textbook, essays about what it means to prove something or reports describing the significant contributions of well-known mathematicians"(Urquhart, 2009). Writing can be "used to assess attitudes and beliefs, mathematics ability, and ability to express ideas clearly" (Russek, 1998).

Writing in mathematics can come in many forms and serve many purposes. It "has been proposed as a learning vehicle by many theorists"(Jurdak & Zein, 1998). One function could be to improve students' proficiency in proof writing in high school geometry as well as their overall mathematical communication abilities. Tami Martin and Sharon McCrone (2003) establish that proof and reasoning skills are foundational for mathematics learning, but research also shows that many students struggle with geometric proof. The idea of writing down mathematical thoughts using something other than variables and numbers is a foreign concept to many.

The overall goal of this study is to find a way for all teachers to increase students' success with writing proofs as well as a higher level of confidence in their ability to write proofs, paired with a better understanding of how to communicate mathematically. Students enrolled in

an Honors Geometry course were given assignments including journals and expository writing assignments on a weekly basis beginning the second month of school to increase their exposure to writing in various forms in mathematics. Each assignment required 10-20 minutes of in-class time as well as time outside of the classroom for its completion. The students were also given a test of basic proofs 4-5 times during the school year to monitor their growth in writing proofs.

The proof test, journals and expository writing assignments were all evaluated using a rubric created and tested by Yvonne Chimwaza (Chimwaza, 2012). I wanted to track growth in writing skills and in the understanding of how to write mathematically. A survey of student attitudes was conducted at the conclusion of the study.

# CHAPTER 2.  LITERARTURE REVIEW

Geometry can be a different kind of mathematical experience for high school students.  It brings with it a new style of learning, a new vocabulary and, for the first time in most curricula, a chance to prove mathematical ideas.  Dickerson (2006) raises the point that, despite the attention the National Council of Teachers of Mathematics gives to the topic of proof writing and its importance to the study of mathematics; many students identify proof writing as a very challenging task.  He also finds that the same weaknesses and misconceptions found in many students are also evident in many teachers.   Despite the fears of students and some of their own teachers, geometric proof is not only a standard in high school curriculum that must be mastered but, more importantly, "[u]nderstanding formal proofs not only deepens students' understanding of mathematical concepts but also prepares students for higher-level mathematics" (Bell, 2011).

The *Principles and Standards for School Mathematics* (NCTM 2000) include the expectation that students at all levels should engage in reasoning and proving.  In the new Common Core State Standards for Geometry, substantial emphasis is present in each subsection on the students' ability to prove theorems and relationships in geometric figures.   "[P]roof is intimately connected to the construction of mathematical ideas, proving should be as natural for students as defining, modeling, representing or problem solving" (Herbst, 2002).  According to Herbst (2002), most people view proofs as a sequence of steps in a two column format, with statements written on the left and reasons on the right. He finds these *two column proofs* tend to be used to show an apparently obvious conclusion rather than a reasonable argument to validate a mathematical idea.   Drawing from this notion, if students are able to understand the process and purpose of proof writing instead of simply a memorization of steps, proof can be used as a problem solving activity and to provide confirmation of mathematical ideas.

Researchers have long argued that the act of writing a proof has goals far beyond the structure and conclusions found in a proof. Harold Fawcett argued that "learning how to do proofs in geometry is a skill needed by educated citizens because it prepares them for the task of analyzing a text logically and to reach conclusions" (Gonzales & Herbst, 2006).

According to research conducted by Martin and McCrone (2003), we know that students continue to struggle and have difficulty writing proofs. This fact is well established in the literature. However, there is insufficient research investigating how pedagogical choices of the teacher and methods used to teach proof affects the students' ability to write geometric proofs. Why does the struggle exist, and what can be done to help students find success with writing proofs?

Michelle Cirillo (2009) writes about 10 things a teacher should consider prior to teaching proofs in geometry. She proposes that students do not engage in activities at earlier levels to prepare them for the task of proving. This points to an issue with curriculum. A teacher must decide what activities are appropriate to engage students and aiding them in writing of geometric proofs. Cirillo states that "if students have not had sufficient problem-solving experience before the geometry course, they are likely to find doing proofs unfamiliar, challenging, and frustrating experience. Again, this is a curricular issue as well" (Cirillo, 2009).

A key aspect of proof-writing is a student's ability to reason mathematically. NCTM's *Principles of Standards and Teaching* groups reasoning and proof together as one of the Process Standards. "[I]t is important to give students opportunities to build their reasoning skills and aid their understanding of the proof process. Teaching students how to do proofs is a difficult task because students often will not know how to begin a proof" (Bell, 2011). Consequently, for

students to begin a proof, they must develop their reasoning skills. This requires ample opportunity to reason mathematically because this “is a habit of mind, and like all habits, it must be developed through consistent use in many contexts” (Cirillo, 2009). One introductory approach to reasoning and proof can come in an algebra course, when “teachers can point out the mathematical reasons that allow us to solve algebraic equations” (Cirillo, 2009). From here, teachers must determine what other tasks can be given to strengthen students’ problem solving and reasoning skill, but this is only a one portion of the solution to a much larger puzzle.

As we begin to unfold the reasons that students struggle with proofs, we find over and over in the literature that many of these struggles are due to the pedagogical choices made by the teacher. Tami S. Martin and Sharon Soucy McCrone of Illinois State University studied the pedagogical choices made by classroom teachers, the influences these choices has on the development of a classroom microculture where proving was a norm and the impact this had on students’ reasoning ability and formal-proof construction ability. They say that “the data from this study suggests that teachers need to be cognizant of the power that classroom microculture and pedagogical choices can have in influencing students’ understanding of proof.” (Martin & McCrone, 2003).

Reasoning skills and problem-solving skills are all key aspects of this solution as found in the literature, but what other tactics might be pursued to assist in this undertaking? To become a confident and competent proof writer, a student must be exposed to writing in other forms in the mathematics classroom. “Writing requires students to formulate and clarify their ideas and, therefore, can contribute to helping students develop these abilities” (Burns, 1995). This can support the task of proving geometric theorems. Therefore, one pedagogical strategy is the use

of a variety of writing assignments.  But in what forms should it occur to have the most successful outcome?

Writing in the mathematics classroom, may be separated into several kids, among them journal writing and expository writing.   Journal writing tends to be informal in nature, where "students usually reflect on some activity or respond to a prompt given by the teacher" (Ishil, 2002).  In contrast, in expository writing "students use writing as an active part of the learning process with in-class writing activities or prompts" (Ishil, 2002).  For a student to become successful in either type of writing, the teacher must understand the goal of the assignment and give all students ample opportunities to engage in the specific type of writing assignment.

Journal writing invites "students to reflect on their learning by expressing their thoughts and feelings about the mathematics they are learning" (Shield & Galbraith , 1998).  When instructing students to employ journal-writing, the teacher serves as the facilitator of the activities and, as such, must determine the topics, frequency, and purpose of the journal entries. Some researchers support the use of daily journal assignments while others do not recommend such extensive usage.  No matter the frequency of use, they can be seen as an ongoing collection of reflections.  In journals, students can be asked to simply reflect on the material learned, comment on their understanding of new topics, explore alternative ways of solving a problem, or engage in a plethora of other discussion activities.  Regardless of the topics assigned and the frequency of use, the benefits of journal writings are unlimited.  "When students write journals, they can be encouraged to express and reflect upon their feelings, knowledge, processes, and beliefs about mathematics, and consequently be helped to cope with negative emotions, learn new content and skills, and be encouraged to reconceive their views of school mathematics" (Borasi & Rose, 1989).

Expository writing can be beneficial to students in many ways that are vastly different from journal writing but are still aimed at the goal of enhancing communication. Expository writing may require thoughts to be thoroughly explained, just as in a proof of a geometric theorem. The use of expository writing in a mathematics course can deepen students' understanding of mathematical concepts because they can be "prompted to explain how to perform a mathematical procedure or to explain why a given mathematical outcome occurred" (Shield & Galbraith, 1998).

Marilyn Burns, in her book, *Writing in Math Class,* presents the idea that "when solving problems, students should be required not only to present answers but also to explain their reasoning" (1995). When students are asked to solve a word problem, teachers should consider not only the symbolic manipulation needed to solve the problem but should also require ordinary language to explain the mathematics occurring in the problem solving process (Ishil, 2002). This should include the explanation of the steps taken, why they steps were taken, and the rule or property that allows this step to be taken. "In trying to articulate their thoughts in words, the students reflect and internalize, which promotes further learning" (Ishil, 2002). Lynn Havens, a teacher of mathematics, found that when she asked her students to write out their answers to word problems as an expository writing assignment, "it forced them to understand and to apply a concept instead of just having to remember the 'trick' to each operation" (Havens, 1989). This resulted in problem-solving with understanding as opposed to the regurgitation of ritualistic steps. She also found that students who wrote "not only improved their mathematical abilities, but … expanded their abilities to understand difficult concepts and communicate this understanding to others" (Havens, 1989). This ability to communicate understanding to others is a critical component to proof writing and yet a problematic task for students to master.

Writing is a powerful teaching tool in the world of mathematics. It can come in many forms and can have a multitude of benefits inside the context of the mathematics classroom. It is "more than just a means of expressing what we think; it is a means of knowing what we think-a means of shaping, clarifying, and discovering our ideas" (Bagley & Gallenberger, 1992). Therefore, if teachers can view geometric proofs as a form of mathematical writing and can apply tactics previously discussed, proofs can be transformed from a terrifying, isolated task to a comfortable vehicle for the learning of mathematics and a way to apply mathematics knowledge to problem solving.

# CHAPTER 3. NATURE OF THE STUDY

## 3.1 Rationale

Proofs have always been a key component of quality geometry curriculums. Learning to write proofs can be a foundation for the critical thinking processes necessary in geometry, but it can be a monumental challenge for many students and for the teacher. The new Common Core State Standards (CCSS) call for all students to be problem solvers and independent thinkers. The details of what this means are spelled out in the Standards for Practice (CCSS, 2010). “The standards stress not only procedural skill but also conceptual understanding, to make sure students are learning and absorbing the critical information they need to succeed at higher levels” (CCSS, 2010). In the context of geometry, the CCSS expects students to demonstrate this conceptual understanding by being proficient in writing proofs of geometric theorems, including triangle congruence proofs, triangle similarity proofs, and other topics throughout the course such as circle properties and their application, vertical angles, triangle sum, and angle pairs on parallel lines to name a few.

In the summer of 2011, I began to research ways of strengthening my teaching of proof writing and look for possible alternative approaches to the process of proof writing. Despite the incredible amount of research about the benefits of writing in mathematics, I quickly learned that there was not much literature that contained clear, specific and applicable directions.

I saw great value in helping my students become better writers. I began to realize that we, as teachers of mathematics, rarely ask our students to write about the mathematics they are learning, so we throw them into proof-writing unprepared when they reach the geometry course. Why are we surprised that they struggle? My plan emerged from this challenge. My goal was to

develop a plan to increase students' ability to write proofs and to improve their comfort level with writing proofs.

The literature supports the idea that writing leads to better conceptual understanding of mathematical subject matter and improved problem-solving skills. I believed that if I exposed my students to more writing in the geometry classroom that writing in mathematics would no longer be perceived as a foreign and unwelcome expectation. If writing was a common component of the course, the process of writing a proof would simply be another form of writing. It would become as comfortable as solving a linear equation, thereby lessening the worries and anxieties that accompany proof assignments. My goal was to move the students to a higher level of confidence in their ability to write proofs, a better understanding of how to communicate mathematically, and increased skill in the actual execution.

**3.2 Population and Setting**

The data collected for this thesis was obtained at Parkview Baptist High School, a K-12 private school, in Baton Rouge, Louisiana. Parkview Baptist is located in south Baton Rouge off of Airline Highway. The socioeconomic level of the school is predominantly middle class with approximately 5% of the high school receiving any financial aid. The students tested were all enrolled in an Honors Geometry course and were in grades 9-10 during the 2011-2012 (Year 1) and 2012-2013 (Year 2) school years. For students to remain enrolled in honors courses, no grade lower than a B- may be earned for a semester in the previous course. The median score of the Year 1 students on the PLAN test was a 19 and the median score of year 2 on the same national test was a 19.5. The PLAN test is a national test that helps high school students identify their college and career readiness as compared to other students nationally.

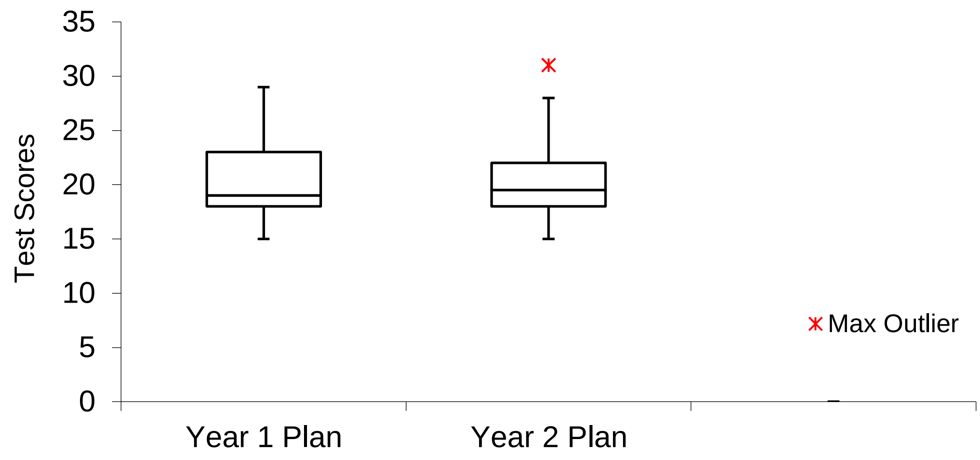



Figure 1: Year 1 & Year 2 PLAN Scores

In 2011-2012, there were 17 female and 18 male students enrolled in the course. All of the 35 students were white, non-Hispanic. In 2012-2013, there were 16 females and 18 males in the course. Of the 34 students, 2 were African American and all others were white, non-Hispanic.

### 3.3 Geometry Honors Curriculum

At Parkview Baptist High School, teachers are allowed much freedom in the design of curriculum. The honors geometry course uses Michael Serra's *Discovering Geometry* textbook on Euclidean Geometry as an aide and to provide homework problems. The course follows the text with regard to concept sequence and grouping, but the teacher selects the specific emphasis and timing.

In the first semester, the major topics covered were Chapter 1: Introduction to Geometry, Chapter 2: Reasoning in Geometry, Chapter 3: Straightedge and Compass Constructions, Chapter 4: Triangles, and Chapter 5: Polygons. In Chapter 1, the focus is on the basic

terminology necessary to understand the language of geometry. This serves as a basic overview for the remainder of the school year. In Chapter 2, inductive and deductive reasoning is studied. This is where the students are first presented with the idea of writing a proof. It is introduced with basic algebraic proofs, and they are taught the 2-column format. Following the introduction of proofs, parallel lines are presented and explored and properties of angle relationships are proved. This is the first time the students are asked to prove geometric theorems and thus the challenges begin.

In Chapter 3, geometric constructions with straightedges and compasses are explored. This is the first time most students use a compass, and it provides validation as to how and why many geometric properties exist, such as perpendicular and angle bisectors. Moving to Chapter 4, students are finally confronted with a heavily proof-based curriculum in the study of triangles. Triangle properties, such as angle sum, are studied and students are asked not only to learn the properties/theorem but to prove why they are true using previously learned facts. In addition, students are required to give complete details when proving triangle congruence using ASA, SSS, SAA, and SAS.

The first semester is concluded with polygon properties in Chapter 5. This chapter is similar to the structure of the fourth chapter on triangle congruence in that the students are again asked to learn theorems and properties in addition to proving why they are true. The culmination of this semester is a midterm exam inclusive of writing proofs.

In the second semester, the major topics covered were Chapter 6: Circles, Chapter 8: Area, Chapter 9: Triangle and Polygon Similarity, followed by a combination of several grouped

chapters covering the Pythagorean Theorem, its converse and applications, Special Right Triangles, and Basic Trigonometry, and lastly, Chapter 11: Volume.

When the study of circles is introduced in Chapter 6 many definitions are reviewed, and new theorems are introduced and proved. The new theorems are used to solve missing measurement problems within circles and also used to measure and prove congruence of segments and arcs within the circle. From here, the students study the area of geometric figures. During this chapter there is less of an emphasis on proving theorems, but students do work on proving the area equations when given the area of a rectangle or parallelogram. The purpose of writing these proofs is to further instill in the students the idea that in mathematics, everything can be proven.

In Chapter 9: Triangle and Polygon Similarity, a heavy emphasis on proving returns. This chapter is structured much like the chapter on triangle congruence from the first semester. A level of relaxation due to familiarity in noticed which enables the students to easily prove why triangles and polygons are similar.

From this point in the year, the focus shifts to the Pythagorean Theorem and right triangle trigonometry. The traditional structure of textbook chapters is no longer used but rather a combination of material from a variety of chapters is utilized to expose the students to as much trigonometry as possible in a short amount of time. During the 2012-2013 school year, the students used their knowledge of writing to understand trigonometric identities. No proofs occur during this portion of the curriculum. At the conclusion of this material, a study of volume ensues in Chapter 11. Due to the brief time remaining in the school year prior to exams, this material is presented and problems are solved using all volume formulas. Time is also devoted

in reviewing basic Algebra techniques for solving for various measurements within a given problem.  The conclusion of the course is a teacher-constructed final exam and is cumulative of the entire year.

**3.4 Design of the Study**

I introduced journal writing and expository writing in my two honors geometry classes in the form of tasks.  The journal writings were used for students to reflect on their learning processes and to comment on features of the course that they felt beneficial to them.  The journals gave the students an opportunity to become comfortable when writing in a mathematics class and an opportunity to write without the stress of getting a correct answer.

The expository writing tasks called for written explanations of solutions to word problems.  These writing assignments covered concepts the students had already learned.  Each student was responsible for giving a detailed description of how to solve a problem.   They were asked to include all details and rules used in solving the problem so that a person with weak mathematics skills could easily follow the work.

The writing assignments were kept throughout the year in a file for each student and used for evaluation to determine growth made in the students' ability to reason and write mathematically.  If the addition of writing assignments into the curriculum really does enable students to develop their problem solving skills, an improvement in their proof writing should be evident.  With repeated opportunities to reason, write and justify arguments, changes should be evident in the work.

I created at test to evaluate growth.  It consisted of an algebra problem, a geometry problems and a geometric theorem to prove.  All three items required writing. The rationale

behind this was to give the students a problem that they would be familiar with from previous mathematics courses, making them more comfortable with the two problems which were new to them. The same test was given at the start of the school year and each quarter of the year thereafter. In evaluating student work, I looked for increases in details given, thoroughness of explanation, and accuracy of justifications. This test will be labeled the "Proof Test". (See APPENDIX A)

Finally, a survey was given to the students involved in the study to determine how they felt about the writing they had done in mathematics prior to the year in honors geometry, their attitudes about proof writing, journals and expository writing and their feelings and emotions about the year of proof writing. The surveys aided in determining if the use of writing assignments improved attitudes about proof writing.

# CHAPTER 4. PROCESS FOR YEAR 1 (2011-2012)

In Chapter 4, I discuss the process used to assign the journal and expository writing tasks. The timing of the first Proof Test (described previously) is also given. In addition, the rubric used to evaluate the students' work on the expository writing and the Proof Test is given.

At the start of the school year, the students began completing the journal assignments described previously. They were given 5-10 minutes at the start of class to complete their journal based on a writing prompt. The selected prompts were chosen, to evaluate where the students were in their feelings about writing, their prior experience with writing and other thoughts about their overall progress in geometry.

Next, I had to determine how to best introduce mathematical proof. I began the school year with a section covering two-column proofs of algebraic facts, using all rules that the students were familiar with from their study of Algebra I. I hoped that completing algebraic proofs would provide the students with an opportunity to explore the idea of proof in the context of concepts which they were comfortable with. After the section was completed, the students were tested using the Proof Test to serve as a base line for the data.

An important goal was for my students to grasp the level of specificity that should exist in the expository writing assignments. To achieve this goal, our first expository writing task was the classic "explain how to make a peanut butter and jelly sandwich". This gave the students an opportunity to write about something they were comfortable doing. Demonstrations of their written instructions were performed in class. Many of the students left out basic instructions, such as remove two slices of bread from the bread bag, remove the lid to the peanut butter jar, or insert the knife/spoon into the jar and remove the peanut butter/jelly, etc. After the

demonstrations were complete, we discussed the steps they had omitted and why it was important for them to be included for a thorough explanation. As a class, we discussed the importance of clarity with regard to each step in the sandwich-making process and how this corresponded to the importance of clarity in each step in a mathematical proof. This helped the students understand that even if a fact seems obvious to them, it still must be included in a proof. After this assignment, the remainder of the expository writing assignment tasks were a mixture of algebra-based word problems (mostly early in the course) and complex geometry problems selected from various texts.

All writing assignments were kept in each child's folder and not returned after their evaluation. The journal assignments were kept for reflection and contributed to grades only as an indication of participation. The Proof Test was administered according to the schedule previously described. The expository writing assignment tasks and proof tests were evaluated using an adapted version of Yvonne Chimwaza's grading rubric (2012). This grading rubric allowed me to focus on and evaluate key elements of a well written proof without getting too specific and missing overall improvement.

| **Geometry Expository Writing and Proof Test Rubric** | | | | |
|---|---|---|---|---|
| Problem # | Use of Vocabulary<br>1 No<br>2 Yes | Correct Vocabulary Usage<br>1 No<br>2 Partial<br>3 Yes | Grammatically Correct<br>1 ∠50%<br>2 50%<br>3 >50% | Mathematically Correct<br>1 ∠50%<br>2 50%<br>3 >50% |
| 1a | | | | |
| 1b | | | | |
| 2a | | | | |
| 2b | | | | |
| 3a | | | | |
| 3b | | | | |

Figure 2: Geometry Expository Writing and Proof Test Rubric

# CHAPTER 5. FINDINGS FOR YEAR 1 (2011-2012)

## 5.1 Writing Samples

To describe the changes observed in my students' proof writing ability, I will use the work of three students chosen as typical representatives of larger groups. I will concentrate on the first and last proof test and two expository writing assignments. One of the expository writing assignments was taken from the beginning of the year and the other from the late spring. All students were graded using the rubric designed to evaluate vocabulary, writing skills and mathematical correctness. These results will provide evidence of the benefits of the increased use of writing assignments.

I decided that I wanted to classify the students into groups based on skill level and attitude. The grouping was done by examining their rubric scores, reviewing common mistakes, and evaluating their attitudes about the writing assignments. Three groups: Group A, Group B, and Group C, were evident after analyzing the work of all the students. Group A was the most mathematically challenged. The students in this group needed a great deal of work with their reasoning skills and written mathematical communication but were very willing to work hard to improve. Group B were students who seemed to have an understanding the skills they needed but resisted doing the work. They felt that the steps were unnecessary; they were headstrong in their opinions and made no efforts to improve their writing assignments. Group C represented students who were shocked by the difficulty of the initial proof test and were determined to master the art of proof writing. These were the highest achieving students in the two honors classes. They constantly reread, revaluated and rethought their work in an effort to express their mathematics more coherently and accurately. Students A, B, and C were selected as

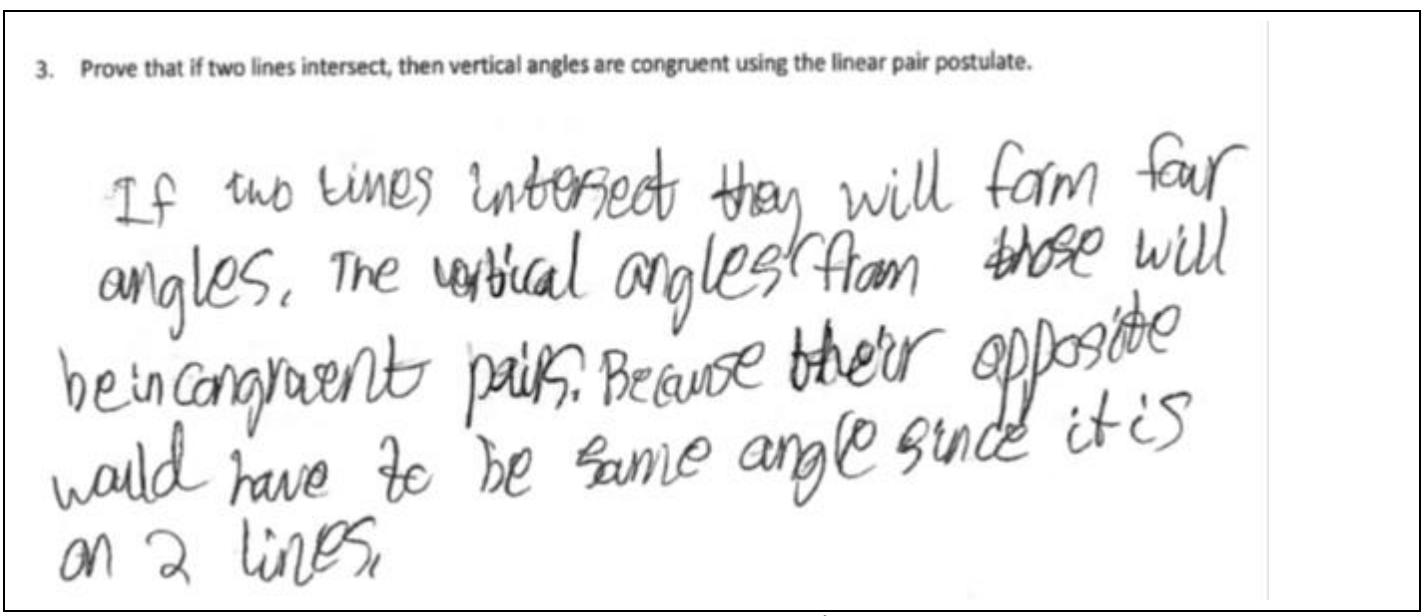
characteristic of their group because their answers used similar language and had similar mistakes to many of the other students in their representative groups.

### 5.1.1 Proof Test #1

Question three of the Proof Test focuses on the student's understanding of why vertical angles are congruent when given the Linear Pair Postulate which states that if two lines intersect then linear pairs are supplementary. This question requires the students to visualize the intersection of two lines, to know the linear pair postulate, to understand its meaning and to know where to locate the vertical angles. In addition, they must set up two equations and use the substitution property of equality to show that the vertical angles are in fact congruent.

| **Proof Test 2011-2012** |
| --- |
| Prove that if two lines intersect, then vertical angles are congruent using the linear pair postulate. |

Figure 3: Proof Test 2011-2012

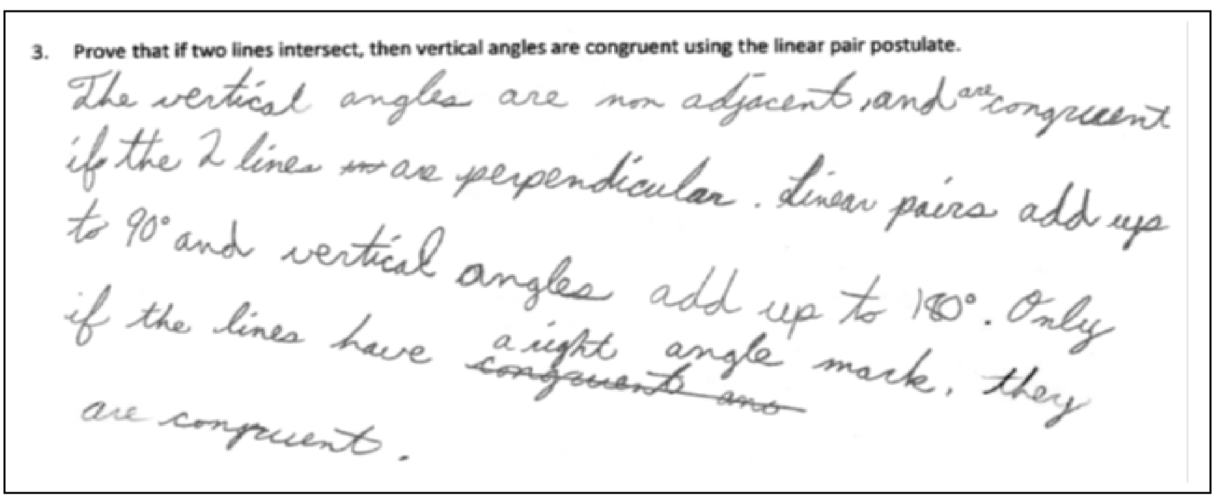

3. Prove that if two lines intersect, then vertical angles are congruent using the linear pair postulate.

If two lines intersect they will form four angles. The vertical angles from those will be in congruent pairs. Because their opposite would have to be same angle since it is on 2 lines.

Figure 4: Student A Proof Test #1

After evaluating this proof with the rubric, it is evident that Student A began with a plan of how he wanted to justify that vertical angles were congruent but his plan falls apart as he writes. He failed to use vocabulary and when he did it was less than 50% correct. He also did not use correct grammar nor have his work mathematically correct. Student A had an obvious understanding of the image of 2 lines intersecting but failed to draw a picture to better organize what he was trying to convey to the reader. He knew that his vertical angles would be congruent but failed to use the linear pair postulate to make this conclusion. Therefore, he was not mathematically correct in his statements. He also did not use his mathematical vocabulary to help explain his reasoning. We can also see a lack of familiarity of vocabulary when he uses the phrase “vertical pair” instead of vertical angles or linear pairs.

This work demonstrates to me that I need to work with the students more on their use of vocabulary and make the students understand that we cannot simply state the fact we are trying to prove and say we have done a proof. Even with the basic algebraic proofs that were written prior to this proof test, Student A is struggling to grasp the meaning of a proof but by writing more than a simple one sentence answer, I also know he is willing to work on this skill.


3. Prove that if two lines intersect, then vertical angles are congruent using the linear pair postulate.

The vertical angles are non adjacent, and are congruent if the 2 lines ~~an~~ are perpendicular. Linear pairs add up to 90° and vertical angles add up to 180°. Only if the lines have a right ~~congruents are~~ angle mark, they are congruent.

Figure 5: Student B Proof Test #1

Student B begins with an obvious improvement on use and understanding of vocabulary from Student A when he states that "vertical angles are non-adjacent, and are congruent" but again he is stating a fact he should be trying to prove.  He then moves towards an example or hypothetical situation in which 2 lines would intersect perpendicularly.  From there he confuses his terms, does not correctly use vocabulary and appears to lose track of what he is trying to prove and does not present a mathematically sound proof.  In addition, he does not use correct grammar missing multiple comas and also not capitalizing the first word of his sentence.  It appears that he loses track of the idea that an effectively written proof should be a well-organize, grammatically correct presentation of mathematical facts to draw conclusions from.

Student B also pays no attention to the initial problem telling him to use the linear pair postulate to complete this proof.  From the teacher's perspective, I began to realize that there must be a portion of students in my classes that did not understand the need to use the information the problem gives you and realize that is crucial to successfully completing the proof.

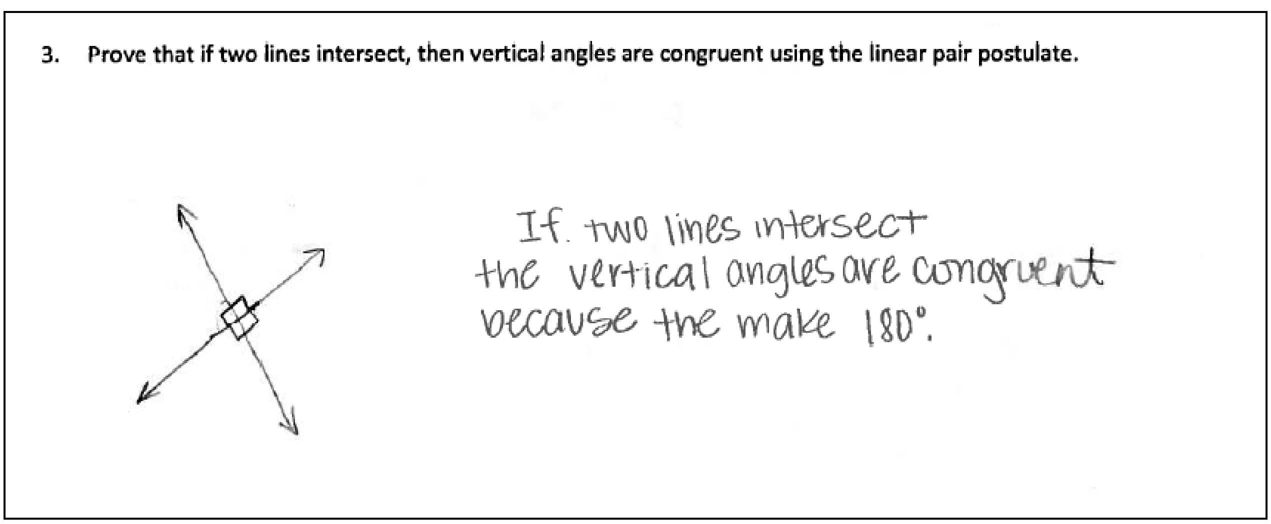



Figure 6: Student C Proof Test #1

Student C is a very conscientious student but the task of proof writing created significant anxiety for her. On her initial proof test, she struggled to grasp the understanding of justifying statements with facts. Not only did Student C fail to use the linear pair postulate like the other 2 students, she also failed to meet any of the goals of the proof. She did not prove the angles congruent, did not use vocabulary correctly, mixing the meaning of congruent and supplementary angles, and had little room for grammatical errors since only one sentence was written.

Overall, each student preserved in writing their proof and although different levels of understanding were evident it is obvious that these students struggled to grasp the idea of proof writing. Following this proof test, the students engaged in the peanut butter and jelly expository writing assignment to help them understand the level of detail needed in a mathematical proof. Demonstrating the importance of each step in the directions of sandwich making was crucial in giving them a greater awareness of the level of detail I would be looking for from this point forward in all of their written work.

### 5.1.2 Expository Writing Assignment #4

After the peanut butter and jelly assignment, the students were given an example of an expository writing assignment (See APPENDIX B) to show them how to effectively use vocabulary, how to pay attention to grammar, and how to be mathematically correct. We discussed the importance of each of these items to a well written mathematical exposition. They then began completing expository writing assignments every few weeks to help them begin to develop a level of comfort with writing in mathematics. In an attempt to begin our expository

writing assignments with something the students are more comfortable with, the first three problems the classes completed involved algebraic word problems.

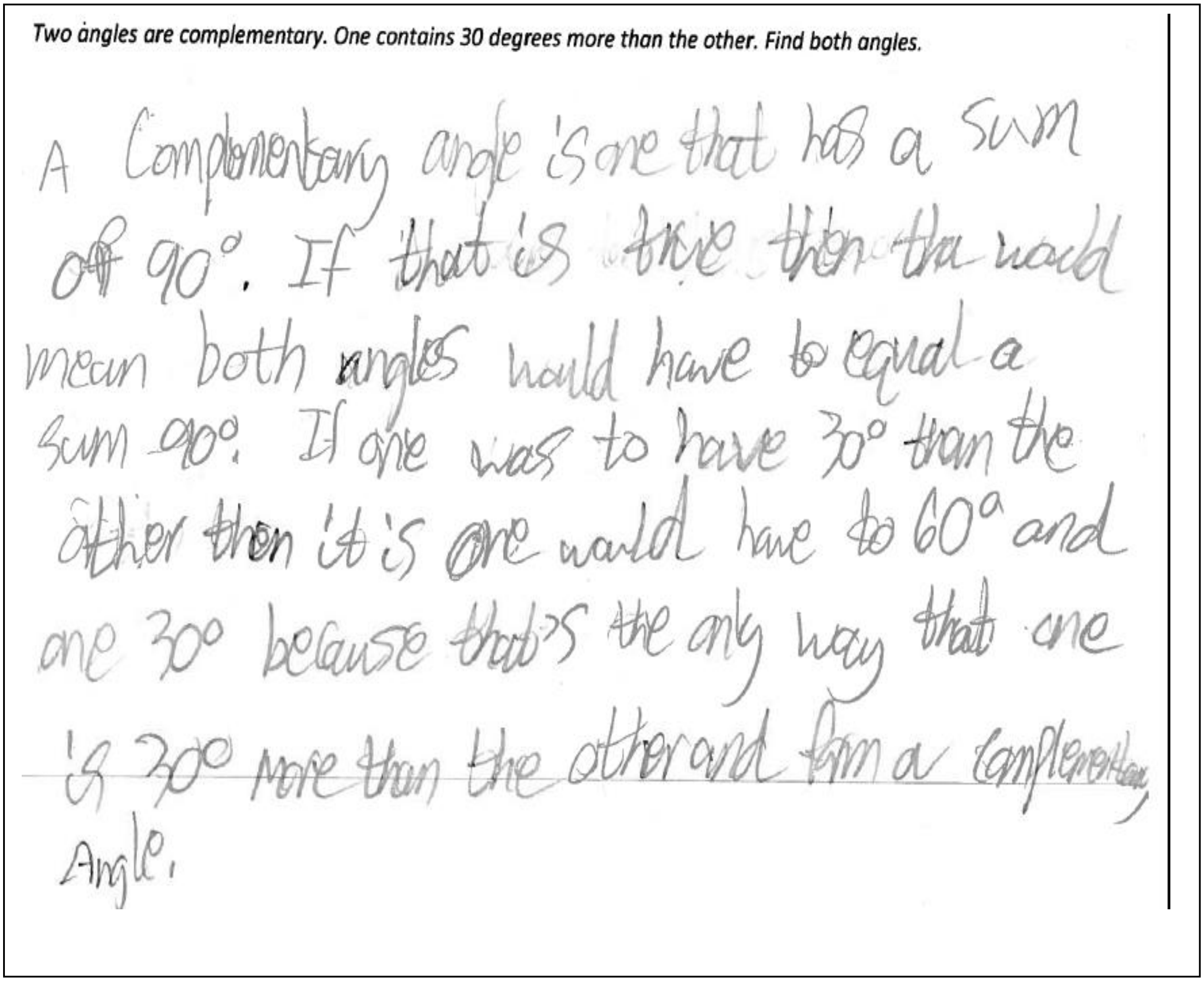
Assignment 4 was first expository writing assignments to deal with geometric terms that were not covered in middle school. Here the students would need to know the meaning of complementary angles and how to set up an algebraic equation to show the relationships between the two angles.

> Two angles are complementary. One contains 30 degrees more than the other. Find both angles.

Figure 7: Expository Writing 2011-2012 Assignment #4

Students could let $x = measure\ of\ the\ smaller\ angle$ and $y = measure\ of\ the\ larger\ angle$ resulting in $x + y = 90°$. Then if they knew that $y = 30 + x$ since it was 30° more than the other angle, they could substitute this into the original equation to obtain $x + x + 30° = 90°$. Students could then simplify the equation by adding like terms to get $2x + 30° = 90°$. Then they would need to subtract 30° from both sides of the equation using the subtraction property of equality to get $2x° = 60°$. Using the division property of equality they could divide by 2 on both sides of the equation to get $x = 30°$ giving us the measure of the smaller angle. Students would then need to substitute $x = 30,°$ into $y = 30 + x$ to solve for the larger angle. In doing so, we would learn that the larger angle measures 60°.

Student A has an understanding of the meaning of the word complementary at an associative level. He associates the words “sum” and “90°´with the word “complementary”. He fails to articulate the idea that complementary is a relation between two angles and not a single angle with a specific sum.

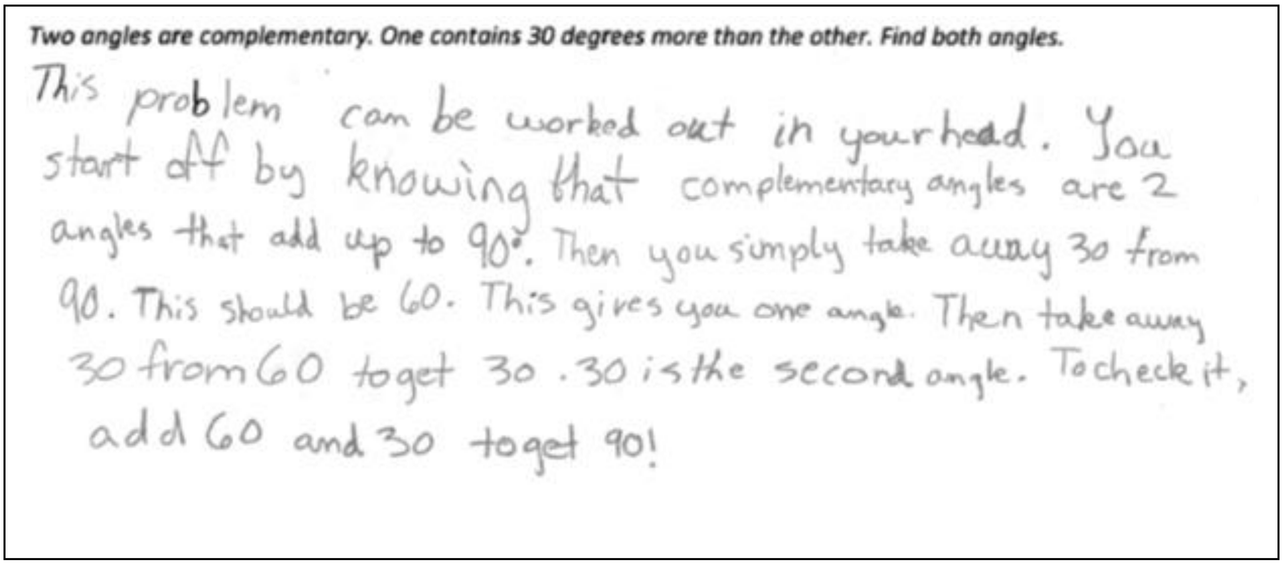

Two angles are complementary. One contains 30 degrees more than the other. Find both angles.

A Complementary angle is one that has a sum of 90°. If that is true then tha would mean both angles would have to equal a sum 90°. If one was to have 30° than the other then it is one would have to 60° and one 30° because that's the only way that one is 30° more than the other and fam a Complementary Angle.

Figure 8: Student A Expository Writing Assignment #4

Student A does not try to explain how to determine the measure of the two angles and does not define variables or set up equations, as he was instructed. He does come up with the

correct angle measures but his sentences become very long and the grammar deteriorates. It seems likely that he understood that he was looking for two angles that differ by 30° and sum to 90°. His answer would have been stronger if he had defined his variables explicitly and set up equations to present the facts of the problem and then solve them. On the other hand, by attempting to use more vocabulary and thinking through his arguments he has made gains from his original proof test.


**Two angles are complementary. One contains 30 degrees more than the other. Find both angles.**

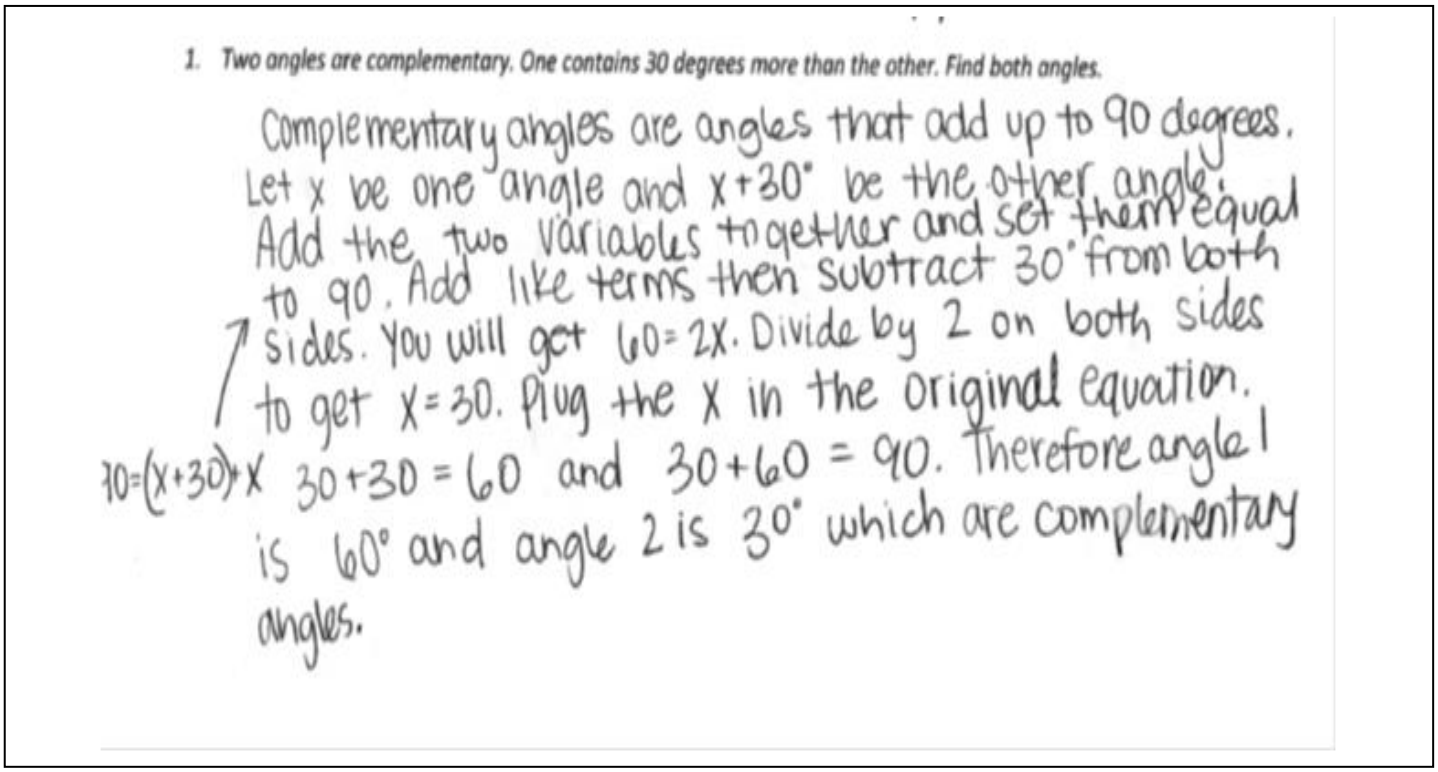
This problem can be worked out in your head. You start off by knowing that complementary angles are 2 angles that add up to 90°. Then you simply take away 30 from 90. This should be 60. This gives you one angle. Then take away 30 from 60 toget 30. 30 is the second angle. To check it, add 60 and 30 toget 90!

Figure 9: Student B Expository Writing Assignment #4

On this writing assignment, Student B's answer shows variances in the level of understanding from Student A. Student B begins by stating the meaning of complementary angles. He goes on to discuss the math he did to solve the problem but fails to use any equations and also does not use appropriate mathematical vocabulary. He also skips one step in the angle calculation but due to the numbers used still gets the correct values for each angle.

Student B has a major flaw in the reasoning he used to solve the problem that only works due to the values given in the original question. He may have known the answers, but he fails to

correctly explain how to solve for them mathematically.  Student B does include a step of mathematically checking his answer with the meaning of the phrase complementary angles when he add his to angles to make sure they do indeed sum to 90°.  This shows he has a good understanding of what he was attempting to do in this problem even though there are reasoning errors.



1. Two angles are complementary. One contains 30 degrees more than the other. Find both angles.

Complementary angles are angles that add up to 90 degrees. Let x be one angle and x+30° be the other angle. Add the two variables together and set them equal to 90. Add like terms then subtract 30° from both sides. You will get 60=2x. Divide by 2 on both sides to get x=30. Plug the x in the original equation. 30+30=60 and 30+60=90. Therefore angle 1 is 60° and angle 2 is 30° which are complementary angles.

7

90=(x+30)+x

Figure 10: Student C Expository Writing Assignment #4

Student C shows the most improvement from her original proof test in this writing assignment.  She improves her score because of her excellent use of vocabulary and mathematically correct equations used while solving the problem.

Student C begins by letting me know she knows and understands the meaning of the term complementary angles but fails to understand the difference between an expression and an

equation.  She then defines the variable she will be using the in problem to solve for the missing angle measures but she makes the assumption that $x$ will represent the measure of the smaller angle.  Although she could have been more specific in the definition of the variables and how she came up with them, they are clearly stated. Student C then describes what she does to this equation but realizes she has forgotten to state the equation used and writes it on the side. This shows she has overlooked a detail but later realizes its importance. She does a good job of explaining with mathematical vocabulary how she arrives at $x = 30°$. The student has not referred back to the meaning of $x$. She realizes that knowing that $x = 30°$ will help her solve the problem, but she has lost sight obvious fact that she now knows one of the angles. Not referring back to the original meaning of a variable is a common error amongst many students.

At the "plug in" state, she realizes that she needs to link the information $x = 30°$ to the original equation. She is not precise in describing how that linking occurs, using the phrase "plug in" and even suggesting an uninformative operation.

From this point forward through the next sentence, she loses her mathematical formality that she had achieved in the start of the exposition but still completes her problem correctly. Finally, she summarizes her results in a way that restates what she was attempting to solve for. This assignment shows that Student C had made vast improvements from her first proof test but as is evident by the diminishing formality at the conclusion of the answer we see that there is still room for improvement in her work.

Each student exhibited some level of growth with their work in assignment 4. They attempted to use mathematical vocabulary more, corrected some of their grammatical errors and are slowly beginning to understand the importance of every step of their process being explained.

There are still many gains to be made but in a very short amount of time improvement has been achieved.

From the assessment of this problem many things were learned both about the students and about the problem itself.

1. The problem has a design flaw that interferes with the goal of the task.
2. Student A has an understanding at an associative level.
3. Student B has a flawed logical smoke screen and needs to be challenged with a problem where the equations are needed even by a clever student.
4. Student C needs a more targeted challenge in a) defining variables and b) interpreting the meaning of a solution.

In evaluation of expository writing assignment 4, it is evident that it creates limitations in the evaluation of the students work. It is very easily solved in one's head without the need to show and justify mathematical equations creating a situation where a student can simply report on a solution. In hindsight, this problem should be changed to more complex numbers that must be written in a mathematical equation in order for it to be more effective for determining student progression.

### 5.1.3 Expository Writing Assignment #8

The final expository writing assignment we will explore is assignment eight. In this question, as seen in the figure below, student are asked to solve for the unknown value which requires them to use their knowledge of radii, isosceles triangles, and triangle sum.

*O is the center of the circle. Form an equation in x and solve the equation. Justify each portion of your equation with geometric theorems and/or facts.*

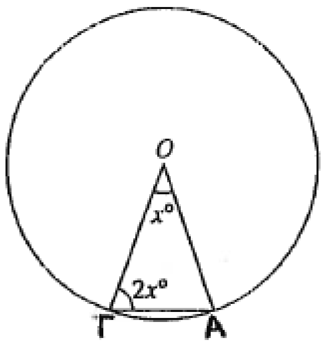
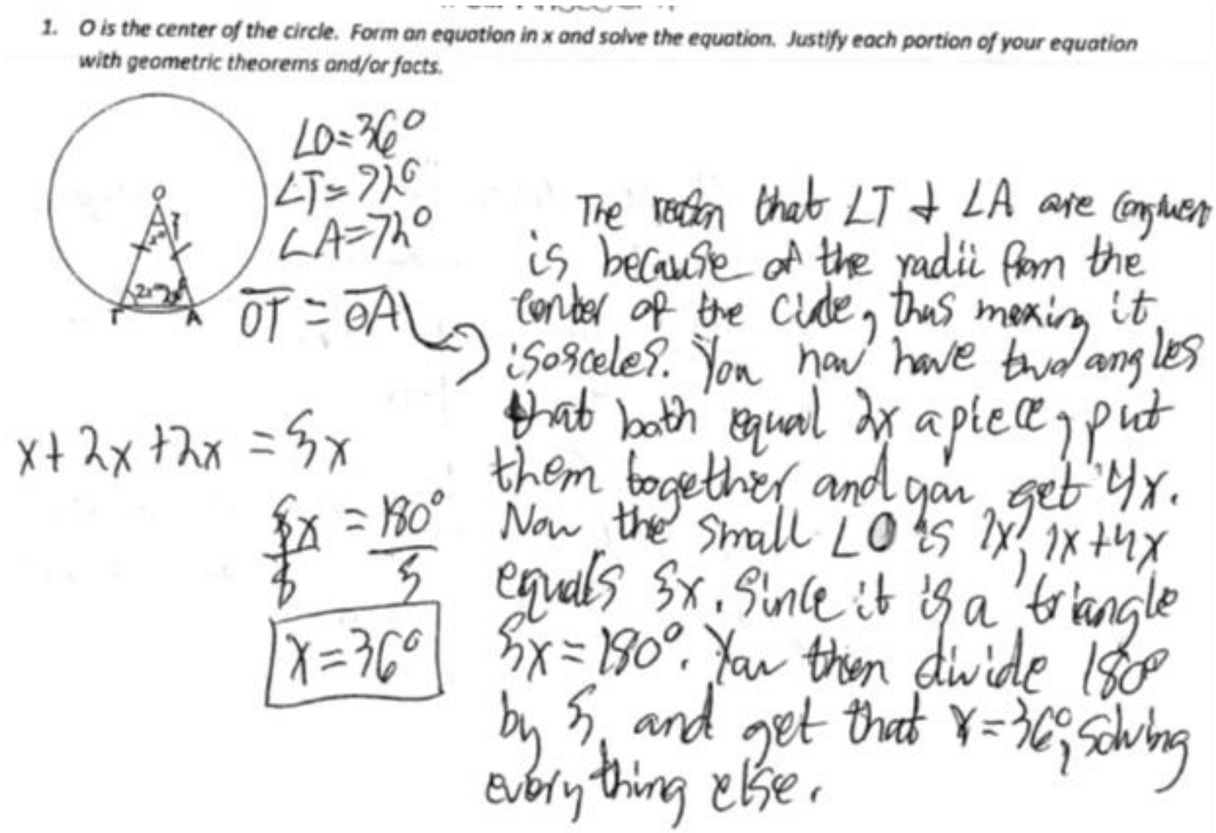



Figure 11: Expository Writing Assignment #8

Students were expected to first notice that $\overline{OT}$ and $\overline{OA}$ are radii of the circle thus making $\Delta OTA$ an isosceles triangle. Then if $\overline{OT}$ and $\overline{OA}$ are the congruent legs then $\angle OTA$ and $\angle OAT$ are congruent because they are the base angles of the isosceles triangle. This makes $\angle OAT = 2x$ also which allows us to set up the equation $2x + 2x + x = 180°$ using triangle sum. By combining like terms, we have $5x = 180°$. Using the division property of equality; we can divide by 5 on both sides of the equation we get $x = 36°$. In the student answers for this problem, I hope to see more thorough explanations to their solutions using vocabulary, equations and justifications of how they arrived at their answers and mathematical correct values for *x*.

Student A appears to have an understanding of what is necessary to solve this problem with the correct justifications. As he begins his explanation, he does not explicitly name his radii and corrects this by adding it to the side of his explanation. He realizes that we have an isosceles triangle though he does not call it a triangle. After he makes this identification, he explains that we have equal angles, but he does not explicitly tell us how we know they are congruent. Student A uses triangle sum to set the expression equal to 180 degrees and correctly solved for x.

He solved the equation without commenting. The equation was simple, but I did take pains to demand attention to such things in the student's work.



1. O is the center of the circle. Form an equation in x and solve the equation. Justify each portion of your equation with geometric theorems and/or facts.

$\angle O = 36^\circ$
$\angle T = 72^\circ$
$\angle A = 72^\circ$
$\overline{OT} = \overline{OA}$

The reason that $\angle T$ + $\angle A$ are congruent is because of the radii from the center of the circle, thus making it isosceles. You now have two angles that both equal 2x apiece, put them together and you get 4x. Now the small $\angle O$ is 1x, 1x+4x equals 5x. Since it is a triangle 5x=180°. You then divide 180 by 5 and get that x=36°, solving everything else.

$x + 2x + 2x = 5x$

$\frac{5x}{5} = \frac{180^\circ}{5}$

$\boxed{x = 36^\circ}$

Figure 12: Student A Expository Writing Assignment #8

In comparison to assignment 4, Student A has made gains in his work by using equations although improvements could still be made in this area and better grammatical skills shown. He is also using the correct mathematical terms/vocabulary. Although Student A still represents a very weak group, he is continuing to strive for better work. In his next assignments and his proof test, I hope to see that he continues to improve his work and apply what he has learned.

Student B also shows gains in his level of understanding of what is necessary to thoroughly explain his solutions with justified steps. He identified the radii and knew that they were congruent.

Since we know that O is the center of
the circle, we know that $\overline{OT}$ +
$\overline{OA}$ are radiuses. Since they
aree raduses, they are
$\cong$. Next, we know $\angle OAT$ + $\angle OTA$ are
$\cong$ because $\angle OAT$ is opposite from
$\overline{OT}$ + $\angle OTA$ is opposite from
$\overline{OA}$. So to get x, you add all
of the angles and set them equal
to 180. $\rightarrow 5x = 180$. You should get
$X = 36$ + voila, here is the
answer.

Figure 13: Student B Expository Writing Assignment #8

From this point, he identified that the base angles were congruent but failed to mention that this was because in an isosceles triangle angles opposite equal sides are equal. Including this would be necessary for the completely justified answer I was looking for. As he sets up and completes his equation there is no validation for setting $5x = 180°$ . At this point he should have stated that he was able to do this because the sum of the measures of the angles in any triangle is $180°$. Had he mentioned at the start that we had $\Delta OTA,$ I believe he would have been more likely to justify his equation being equal to 180 degrees. He does arrive at the correct answer of $x = 36°$.

In summary, Student B has an understanding of how this problem is to be solved but he uses 2 principles, base angles of an isosceles triangle are congruent and triangle bum, that he never mentions. He knows them but expectation is that he justifies his work with them. In spite of his errors and lack of justifications, Student B did make progresses from his prior assignments. Even with his strong-willed determination to prove me wrong, Student B's work is continuing to improve.

Student C continues to represent a group of students who are the highest achieving in the two honors courses. Not only does she state the facts or rules that allow her to work the problem but she also summarizes what the rules say in conjunction with how she is applying them so that the reader can clearly follow her though process. Student C is demonstrating in this answer that she understands that as a class we want our expositions to be easily understood by a person with limited mathematical knowledge.

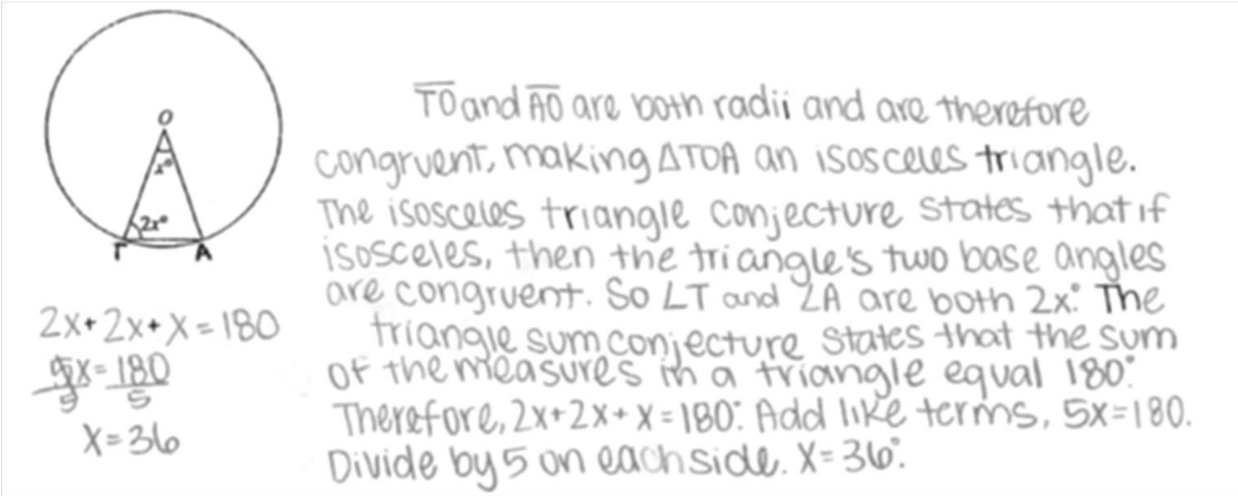


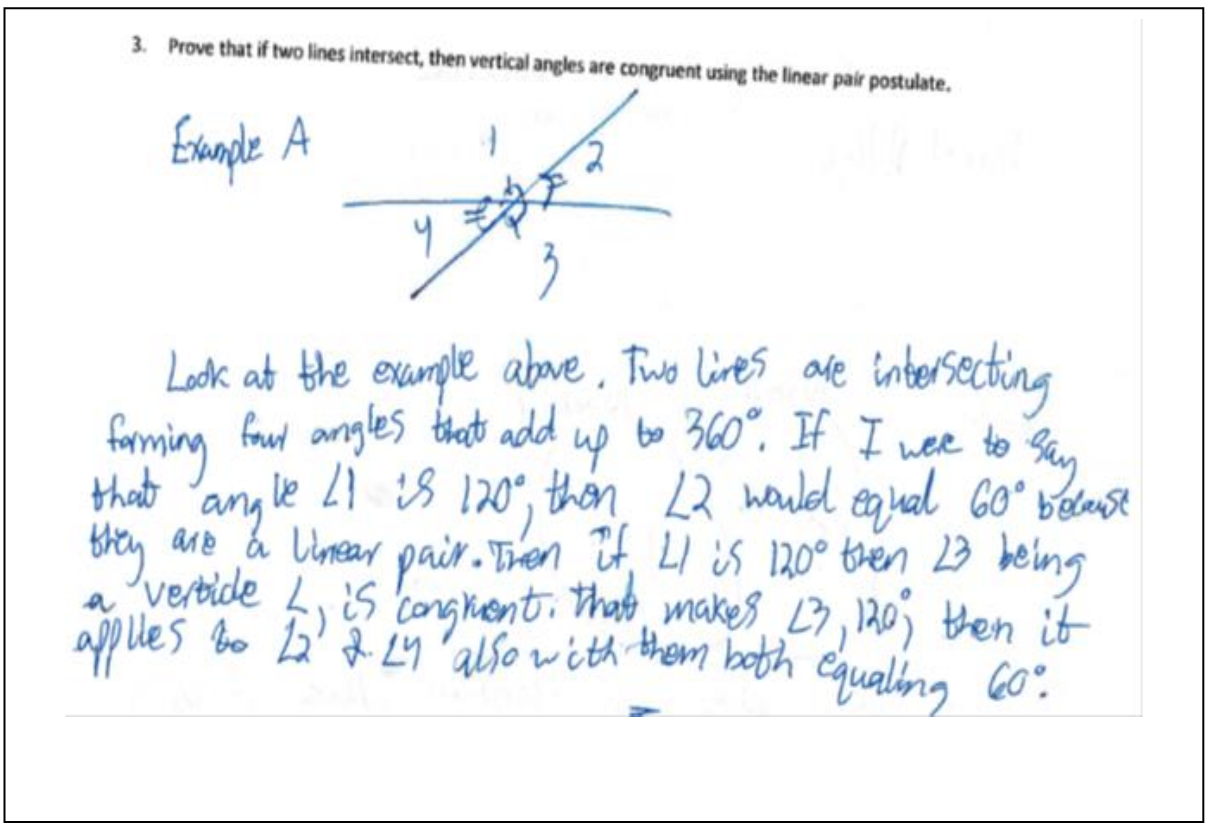

Figure 14: Student C Expository Writing Assignment #8

She clearly identifies the two radii, stating that they are congruent, giving her an isosceles triangle. Next, she explains that isosceles triangles have base angles that are congruent making $\angle T$ and $\angle A$ congruent, thus being both $2x$. Moving from this fact, she states that the measure of a triangle is $180°$ and sets up the correct equation. In her concluding steps, she justifies the algebra used to arrive at $x = 36°$. Her assignment does not give the impression that the author rushed in answering and makes the reader comfortable with the steps used to achieve the final answer.

Overall, assignment 8 showed pronounced growth in all 3 of the students from their original proof test in early September. They are continuing to develop an understanding of the level of detail we are attempting to achieve as well as to realize the importance of vocabulary and reasoning necessary to confidently write mathematically.

5.1.4 Proof Test #4

When handing out the last proof test, my classroom was again full of anxiety. Unlike September, it wasn't in fear of not knowing how to write a proof but it was more in fear of not being able to show me how much they had learned. I knew the scores would probably not show as much improvement as I had seen in their expository writing assignments. Students struggle more with topics they find to be abstract, but perfection is a long shot in most educational settings. What I hoped to see in the evaluation of these tests was simply an improvement from test one. I was confident that the negative emotions associated with proofs that the students exhibited in the fall were gone. I sat anxiously awaiting to see if they could truly show growth in their ability to explain mathematically.


3. Prove that if two lines intersect, then vertical angles are congruent using the linear pair postulate.

Example A

1 2 3 4

Look at the example above. Two lines are intersecting forming four angles that add up to 360°. If I were to say that angle ∠1 is 120°, then ∠2 would equal 60° because they are a linear pair. Then if ∠1 is 120° then ∠3 being a verticle ∠, is congruent. that makes ∠3, 120°, then it applies to ∠2 & ∠4 also with them both equaling 60°.

Figure 15: Student A Proof Test #4

In an effort to make his proof concrete, Student A used a pictorial example in which he set an arbitrary value for one of his named angles. Then, he states the fact that the four angles add up to $360°$. He has an accurate picture of the situation he is being asked about, and he has set up a notation so that he can refer to the parts precisely.

Possibly because he is unable to reason in generalities, he hypothesizes that one angle is $120°$. He then uses the linear pair postulate to conclude that another angle is $60°$. At this point, he should have used the linear pair postulate again, to complete the proof of the instance (namely $m\angle 1 = 120°$) that he is considering. However, instead of doing this, he quotes that theorem he is trying to prove.

Although Student A fell into a serious logical error, there is good news found in his work. He knows that his goal is to show that $\angle 1 \cong \angle 3$; but the bad news is that he short-circuited his argument. This is a common weakness in adolescents. The second big accomplishment is that he does not forget that he needs to address both pairs of vertical angles. In reading this work, it is apparent that his exposition and control have improved. He is now able to apply the given information and use this information as an aide to solving the problem. He has improved his grammatical awareness and his use of correct mathematical terms within the proof.

The group of students represented by Student B had become very apathetic by the spring semester. In spite of this, Student B is able to make gains on the final proof test despite his best efforts to avoid progress in his writing.

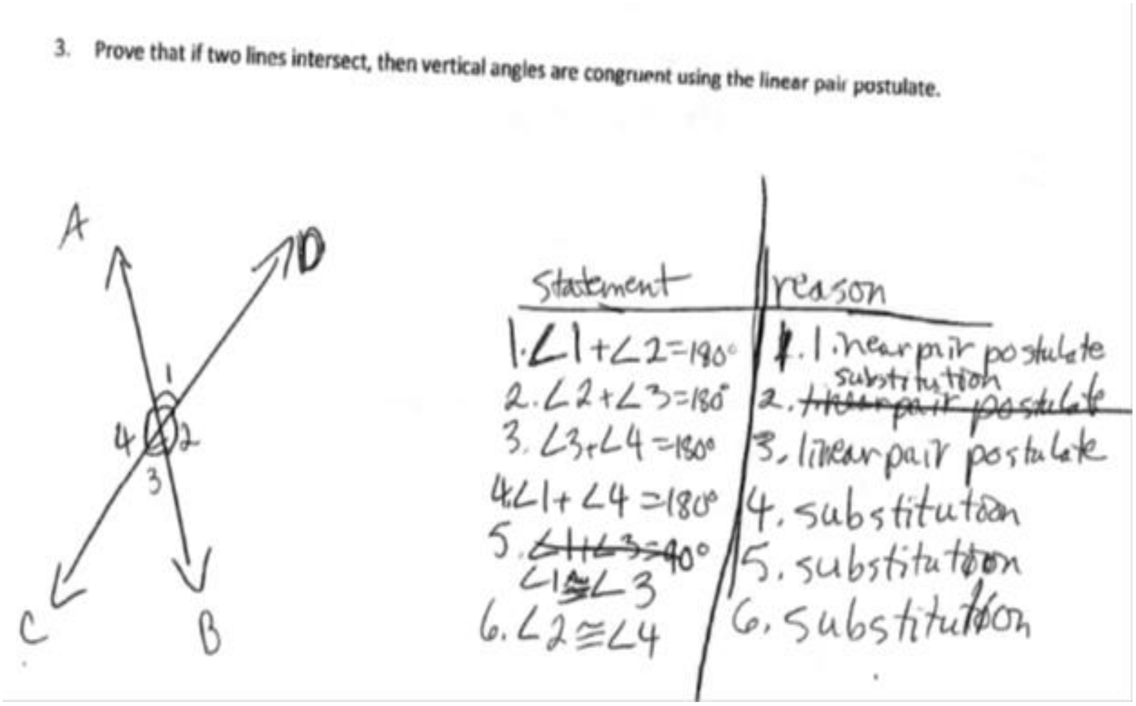



Figure 16: Student B Proof Test #4

Student B also begins the problem by drawing a picture to represent the problem. He continues by using the linear pair postulate to correct equations in steps one and three. In steps two and four, he should have also given the reason of linear pair postulate so his first mathematical error has occurred in his reasoning. He quotes “substitution” as a reason but we don’t know what he means by it. It could be that “$A = C\ and\ B = C\ therefore\ A = B$" is an instance of “substitution” in which case substitution would give $\angle 1 + \angle 2 = \angle 2 + \angle 3$ but then we also need cancellation to get $\angle 1 = \angle 3$.

As we move to step five, he has shown that two angles we know to be vertical are indeed congruent; but again, in his reasoning he has not given a complete justification. He should also identify, using the correct definition, that $\angle 1$ and $\angle 3$ are vertical angles as well as $\angle 2$ and $\angle 4$.

He does attempt to be thorough by showing that both sets of vertical angles are congruent even though omissions of important facts are made prior to this point.

Based on Student B's reasoning and participation in class, I am confident he thought through the steps he was omitting from the proof but his apathy makes them unimportant to him. Although Student B is capable of a much higher score, as his teacher there is only so much I can do to express to him the importance of being able to communicate mathematically. If teachers at all level of mathematics would make writing a part of the curriculum, students like this would be much more willing to develop these reasoning and writing skills.

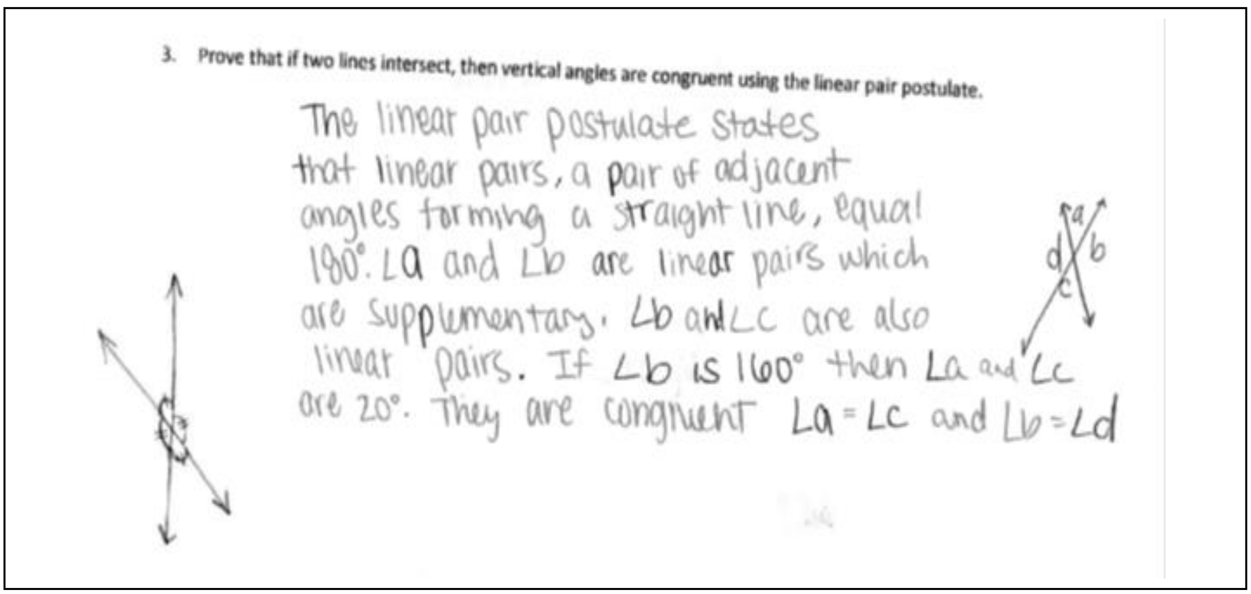



Figure 17: Student C Proof Test #4

Student C and the group of students like her, viewed proof test four as a chance to prove what they had learned throughout the school year. On her original proof test, Student C struggled to grasp the task at hand, which for a high achieving student was discouraging and frustrating. Her work on the final proof test was a complete turnaround, and although it lacked perfection, in each category she was more than 50% correct earning her a high rubric score.

Student C represents the abstract problem with a picture that will apply to any angle measures on two intersecting lines. She then states what she knows based on the linear pair postulate and establishes two linear pairs that share a common angle. At this point, she has a problem with her language. She seems to think "pair" is equal to "angle". She could have said "linearly paired angles." From this point, she doesn't have the mean to express the general idea so she illustrates the pattern with an example. She assigns a value to the common angle and then concludes that it means the other two angles must be congruent. For a stronger answer, Student C should have written out her equations and used substitution to show that they are equal to each other. From there, she could have use the subtraction property of equality to remove $\angle b$ from both sides of the equation leaving her with $\angle a = \angle c$. From here she could use the definition of vertical angles to identify them as such and also the definition of congruence to obtain $\angle a \cong \angle c$ thus proving that vertical angles are indeed congruent. Student C's answer is obviously not without rough spots, but the improvement in her level of understanding of how to write mathematically is clear and noteworthy.

This final proof test showed a level of progress for each student group representative. Group A, represented by Student A, contained 11 students. This group started out very weak and was the lowest performing at the start of the school year. They made large gains in their abilities to write mathematically through the correct usage of vocabulary and reasoning skills within a problem. They also had the added benefit of better conceptual understanding of the material that came from their ability to complete geometric proofs.

Group B had 12 students. Student B's work was representative of this group of apathetic students. Although they began the school year with scores in the middle of the class, their lack of effort caused their scores to dip to some of the lowest in the class. I attribute this drop to the

negative attitudes they, as a group, displayed towards writing in mathematics. They felt math was more about solving a problem and getting the correct answer than being able to justify the process to achieving the correct answer. Despite this group's constant effort to resist the idea of writing in mathematics, they did improve their ability to communicate mathematically by using their vocabulary correctly and using the information given in a problem as an aide to the solution.

The final group of students, group C, represented by Student C also had 12 students. This group of high achieving students continued to strive for excellence in their proof writing and thus continued to improve their overall rubric scores. Many of these students achieved a perfect score on the last proof test and were very excited about this achievement. At the end of the year, they seemed to enjoy the challenge of writing proofs. As a result of their ability to justify their steps with mathematical theorems and use their mathematical vocabulary correctly, their conceptual knowledge of geometry was also the highest in the class. Overall, all the students increased their ability to reason and write mathematically and the attitudes associated with this improvement were profound.

### 5.2 Survey Results Year 1

At the conclusion of the school year, a survey was given through Survey Monkey online to the student in my honors course in order to gauge their beliefs about whether the writing assignment were helpful to them in learning to write proofs. Their beliefs are significant in determining if these activities should be continued in subsequent years.

**#1:** Did you have any experience writing in mathematics prior to the start of this school year?

**#2**: Did you find the peanut butter and jelly expository writing assignment helpful with proof writing?

**#3**: The purpose of our journal assignments was to increase your opportunities to write in mathematics class without the pressure of having to come up with a correct answer. Do you believe this was beneficial to your experience with proofs?

**#4:** The purpose of our word problems (expository writings) was to give you more opportunities to write out explanations to problems and not simply solve them algebraically. Do you believe this was beneficial to your proof writing?

**#5:** Do you think other Geometry Students would have an easier time writing proofs if their teacher did writing assignments with them?

**#6**: Were you anxious about writing proofs at the start of this school year?

**#7:** Please rank the writing assignments we did in class this year in order of helpfulness with 1 being the most helpful and 3 being the least helpful.

**#8**: If you felt more comfortable with the proof test at the end of the year, please select the reason you agree with below.

Figure 18: Student Survey Questions 2011-2012

Table 1: Survey Results 2011-2012 Questions #1-5

| Question Number | Yes | No | # of Students Answering |
|---|---|---|---|
| #1 | 11% | 89% | 28 |
| #2 | 100% | 0 | 28 |
| #3 | 93% | 7% | 28 |
| #4 | 89% | 11% | 28 |
| #5 | 100% | 0% | 21 |

Table 2: Survey Results 2011-2012 Question #6

| **#6** | **# of Students Answering = 21** |
|---|---|
| 76% | Yes, but I am more comfortable with it now because of the activities we did this year. |
| 5% | Yes, but I am more comfortable now. Not because of our activities this year. |
| 19% | No, I was not anxious about proof writing. |
| 0% | No, I am still anxious about proof writing. |

Table 3: Survey Results 2011-2012 Question #7

| **#7**<br><br>**# of Students Answering = 21** | **Ranked #1** | **Ranked #2** | **Ranked #3** |
|---|---|---|---|
| Peanut Butter and Jelly | 89% | 7% | 4% |
| Journals | 4% | 29% | 68% |
| Expository Writing | 7% | 68% | 29% |

Table 4: Survey Results 2011-2012 Question #8

| **#8** | **# of Students Answering = 21** |
|---|---|
| 43% | I was more comfortable with writing proofs in general. |
| 20% | I was more comfortable with the idea of writing in math class from our writing assignments. |
| 31% | I felt more comfortable with my ability to write out my thoughts. |
| 6% | I was not more comfortable with the proof test. |

Upon evaluation of this survey, I was able to see that my students did feel that the writing assignments were helpful to their ability to write geometric proofs. They felt that the Peanut Butter and Jelly assignment was most helpful and not the expository writing assignments as I had believed they would answer. The journals were what they viewed as least helpful.

In the next school year, I hoped to improve the usefulness of the expository writing assignments by providing more structure to the assignments in hopes of the students finding them more helpful. It is my goal that they can reference the structure of the expository writing assignments when they are asked to write a geometric proof. Overall, I view their responses as positive and believe it validates the activities from a student perspective.

# CHAPTER 6: CHANGES, EXPERIENCES, AND RESULTS FOR YEAR 2 (2012-2013)

During the 2012-2013 school year, I once again wanted to implement the use of increased writing assignments to improve student proof writing skills. This method was effective with my students during the 2011-2012 school year, but I wanted to see if slight changes would increase the effectiveness of the writing assignments on students' abilities to write mathematically. This chapter will discuss the changes that were made, the experiences of Year 2, and lastly, the results that were observed.

## 6.1 Changes to Year 2

As I began to evaluate the students' progression in Year 1 of the study, I determined that I wanted to implement small changes to the journals and writing assignments. First, I realized that if the students could see the progression of their writing from September until April they would have a greater level of confidence in their own abilities. Therefore, I decided to have them complete all journals and expository writing assignments in a composition notebook.

After this small change, I decided I wanted to give the expository writing assignments one at a time instead of two problems at a time in order for students to focus on the details and better solve the problems given. In Year 1, I found that many students felt rushed, even with ample time given, to complete both problems and thus rushed to complete their work and were not as careful with their explanations as I believed they could have been.

Yvonne Chimaza (2012) found that students were able to improve their mathematical writing skills and reasoning ability by the use of a writing template. I hypothesized that I could increase the impact of the expository writing assignments upon proof-writing by implementing an adaptation of her "Standards for Mathematical Practice Questions (SMPQ)" template, which I

called "Framework for Expository Writing Assignments." This framework was based on the Standards for Mathematical Practice of the CCSS.

**Framework for Expository Writing Assignments**

1. What is the problem asking you to do? (SMP#1)
2. What steps/information will you need to solve this problem? (SMP#2)
3. Solve and explain your methods of solving the problem? (SMP#3)
4. How can you be more precise in your explanation, if possible? (SMP#6)
5. Write a thorough paragraph explanation of solution.

Figure 19: Framework for Expository Writing Assignments

### 6.2 Experiences in Year 2

In Year 2, the first expository writing assignment remained the Peanut Butter and Jelly explanation. Prior to the assigning of the second assignment, the students were asked to solve a mathematical word problem and give a thorough, written explanation of the solution.

Next, they were given the Framework for Expository Writing Assignments (seen above in Figure 19) and asked to solve the problem again following the framework. After this, they

were given the rubric that was used to evaluate answers and as a class we critiqued the work of the class, discussed what they could have done better and considered alternate ways to solve the problem.

Finally, I gave each student a copy of my solution, and we talked about its strengths as a class. We also discussed the role of the teacher as facilitator during the process of expository writing. I answered questions with other questions, with the hope that this would lead the students to collaborate more. The topics of the expository writing assignments were kept the same as in Year 1, but some problems were changed to better evaluate the students' understanding of a broader variety of skills. The assignments were given every 2-3 weeks.

The "Proof Test" (See APPENDIX A) was still given to the students and used for evaluation beginning in the early fall but the questions and length were changed to focus in on the goals I was trying to achieve and minimize the frustrations of students that occurred in Year 1. These were also graded with the same rubric as the expository writing assignments.

The journal assignments were similar to Year 1, but I increased the frequency with which they were given. I kept a log with the questions that were posed to students to use for reflection of their understandings throughout the school year. Many questions were posed prior to the start of a new chapter to feel out the students comfort level with the coming topics and their emotional state in regards to the proofs we would be writing.

From year 1 to year 2, there was a difference in the writing ability of the students, their attitudes and their familiarity with writing in mathematics. The students in Year 2 had been asked in middle school to solve "Problems of the Week" (POWS) that called for written explanations of solutions to word problems. Since this was implemented the year prior to my

working with the students, they started with more experience in expository writing. Students in Year 2 had already completed the Peanut Butter and Jelly assignment when they were learning about standards for writing in POWS. Consequently, the initial impact of the PB&J assignment was less, but this did allow for more discussion of the relevance to the proof writing process.

The attitudes of the students were different in Year 1 and Year 2. The students in Year 1 were open to the idea of writing in mathematics and willing to engage in the activities with an open mind. They would freely share their ideas of how to prove or solve a problem without reservation or fear of being wrong. In contrast, the students in Year 2 were very resistant and close-minded about incorporating more writing into mathematics. They feared being wrong constantly and only when forced were they willing to share ideas and answers. These attitudes and differences between the two groups are things that I had to adapt to and overcome in analyzing results.

In Year 2, the students were again divided into representative groups. These groups were similar to the groups that were evident in Year 1. This leads me to question of whether the teacher had an influence of the development of these groups, if they exist in other courses as well, and whether they were social groupings that existed outside of class. I suspect that it is the social groupings; however, I have no data to justify this belief.

**6.3 Results for Year 2**

Year 2 presented different challenges from year 1. Since many students had prior experience writing in mathematics, they had a tendency to get bored while the expository writing assignments were introduce and previewed. Believing it would help them to hear the

information; I decided to deliver my introduction even if some students felt it was repeating what they already knew.

The students learned a great deal from expository writing assignment #2 and the review and the discussion of the Framework for Expository Writing which followed. After this, expository writing and journal work were assigned as frequently as the schedule allowed. As the year went on, I observed improvements in the writing, particularly in the use correct mathematical vocabulary and in justifying their steps.

I saw substantial benefit in having the student complete all writing assignments in their composition notebooks. On numerous occasions, students referred to the framework and the example answer as well as their own previous work. Many students commented on how they felt it was very helpful to have all of their work together and organized.

The Proof Test was also given at intervals similar to year 1. As in Year 1, the initial proof test caused many students great anxiety. Students said that they were not nervous about knowing the answers to the question being asked but about being able to express what they were thinking. As in Year 1, the work on the proof tests improved dramatically by May, demonstrating increased ability to reason and write mathematically in the form of a geometric proof.

At the conclusion of Year 2, the survey from the previous year was again given to all 35 Geometry Honors students using Survey Monkey online. The attitudes and beliefs of this group of students were different from the students of 2011-2012. The 2012-2013 students had had more experience writing in mathematics prior to entering my classroom and thus their experiences with our activities were dissimilar. Overall the survey showed that a large portion of

the students found our writing assignments to be of benefit to their proof writing. They all felt that they were more comfortable with the proof test by the end of the school year and nearly two thirds of the students felt that they were more comfortable because of the activities completed in class throughout the school year. The survey questions (see Figure 20) and results (see Table 5-8) are given and answers shown as a percentage.

Based on Year 2, I would consider some changes in the process for future years. The surveys and spoken comments in class suggest removing the journal writing assignments and increasing the frequency of the expository writing assignments.

Upon reflection of the experience gained in Year 2, it is evident that the addition of writing assignments into the Honors Geometry curriculum did improve students' proof writing ability, their confidence in their own ability to write mathematically, their motivations to write well and their understanding of the content studied because the students were able to reason, to use correct mathematical vocabulary, and to justify their steps.

**#1:** Did you have any experience writing in mathematics prior to the start of this school year?

**#2**: Did you find the peanut butter and jelly expository writing assignment helpful with proof writing?

**#3**: The purpose of our journal assignments was to increase your opportunities to write in mathematics class without the pressure of having to come up with a correct answer. Do you believe this was beneficial to your experience with proofs?

**#4:** The purpose of our word problems (expository writings) was to give you more opportunities to write out explanations to problems and not simply solve them algebraically. Do you believe this was beneficial to your proof writing?

**#5:** Do you think other Geometry Students would have an easier time writing proofs if their teacher did writing assignments with them?

**#6**: Were you anxious about writing proofs at the start of this school year?

**#7:** Please rank the writing assignments we did in class this year in order of helpfulness with 1 being the most helpful and 3 being the least helpful.

**#8**: If you felt more comfortable with the proof test at the end of the year, please select the reason you agree with below.

Figure 20: Student Survey Questions 2012-2013 (same survey as 2011-2012)

Table 5: Survey Results 2012-2013 Questions #1-5

| **Question Number** | **Yes** | **No** | **# of Students Answering** |
|---|---|---|---|
| #1 | 50% | 50% | 34 |
| #2 | 88.2% | 11.8% | 34 |
| #3 | 79.4% | 20.6% | 34 |
| #4 | 91.2% | 8.8% | 34 |
| #5 | 94.1% | 5.9% | 34 |

Table 6: Survey Results 2012-2013 Question #6

| **#6** | **# of Students Answering = 34** |
|---|---|
| 64.7% | Yes, but I am more comfortable with it now because of the activities we did this year. |
| 11.8% | Yes, but I am more comfortable now. Not because of our activities this year. |
| 23.5% | No, I was not anxious about proof writing. |
| 0% | No, I am still anxious about proof writing. |

Table 7: Survey Results 2012-2013 Question #7

| **#7**<br><br>**# of Students Answering = 34** | **Ranked #1** | **Ranked #2** | **Ranked #3** |
|---|---|---|---|
| Peanut Butter and Jelly | 44.1% | 29.4% | 26.5% |
| Journals | 20.6% | 35.3% | 44.1% |
| Expository Writing | 35.3% | 35.3% | 29.4% |

Table 8: Survey Results 2012-2013 Question #8

| **#8** | **# of Students Answering = 34** |
|---|---|
| 79.4% | I was more comfortable with writing proofs in general. |
| 29.4% | I was more comfortable with the idea of writing in math class from our writing assignments. |
| 23.5% | I felt more comfortable with my ability to write out my thoughts. |
| 8.8% | I was not more comfortable with the proof test. |

# CHAPTER 7.  CONCLUSIONS

The Common Core State Standards encourage more writing in math classrooms.  Based on the research, it is evident that students struggle and have anxieties about explaining and justifying their mathematical work.  The present project was designed to create a template for the addition of various writing assignments throughout the geometry course to improve students' ability to write mathematically, explain their reasoning, and justify their arguments.

Our analysis of student work in the 2011-2012 school year, shows that when students are asked to write mathematically on a regular basis, the quality of their work will improve.  In the work of the representative students, there was an increase in the use of correct mathematical vocabulary.  When they began their writing assignments, they made little use of the vocabulary they had seen, but as the year progressed, each writing assignment contained more of the appropriate mathematical words. There was an increase the students' ability to use the given information effectively.   At the start of our writing, students paid little attention to the postulate/theorem that was given in the problem, but as we continued to write they realized that this information was needed to correctly complete the assignment and did so effectively. Analysis of the students by the end of the school year showed a greater awareness to the level of detail needed in mathematical writing.  Early on in their proof writing, they did not comment on steps that they did not view as necessary or important.  The omission of an important statement is a common mistake amongst adolescents that must be overcome to construct a well written geometric proof, because what is obvious to the writer is not always obvious to the reader. Finally, there was an increase in the students' ability to justify each statement with the correct mathematical fact or theorem.  Students began the year with statements in their answers without giving the correct fact/theorem needed to include the statement.  As they developed their writing

ability, they began to include justifications for each statement with the correct mathematical fact or theorem.

Overall, the students all showed an increase in their ability to execute a well written geometric proof and to communicate mathematically. Correspondingly, the results of the survey showed improvement in students' attitudes and beliefs. They were more positive and believed the writing assignments were beneficial to their ability to write geometric proofs. The survey also showed that the students' confidence in their own ability to write geometric proofs was improved. Similar results both in written work and survey results were observed in the 2012-2013 school year. This research does show that most of the 35 students ended the year with a better understanding of how to reason and write mathematically.

Based on two years of experience, and a careful analysis of how students reacted, I suggest that if a teacher desires to improve proof-writing skills in a geometry classroom that they adopt the use of journal and expository writing as a routine aspect of their class. I suggest having the students complete all assignments in a composition notebook so they can track and reflect on the growth they make in their own writing. I would assign a journal writing prompt weekly and an expository writing biweekly. To track growth made in the students' ability to write mathematically, I suggest assigning the Proof Test at the start of the school year and at the conclusion of each quarter of the school year. It is important that the expository writing and the Proof Test is evaluated with a carefully chosen rubric focusing on the aspect of the proof-writing in which the teacher wants to see growth. If a teacher is dedicated to instituting these writing assignments, the evidence shows that their students' ability to write geometric proofs will show improvement.

While the main results of my work are the specific suggestion that I can offer for how to make the practice of writing into a routine part of instruction, I have also discovered a few things that I think are worth highlighting. Well-developed content knowledge enables a teacher to better interpret what students are thinking. Without a vast understanding of content the teacher is limited in terms of abilities to make hypotheses on what student are understanding and what they are thinking as they write and justify mathematics. Some content knowledge is specific to the material, but much is how mathematical thinking works in general and how the mind of a student might deal with the problem given. The teacher must be able to use logical terminology and attend to precision in a problem. The teacher needs to help the students understand that the mathematical terminology being used exists to describe a process taking place as one solves the problem. Without extensive content knowledge and ability to use precision when modeling a solution on the part of the teacher, this could be an impossible task. For future researcher interested in helping students increase their ability to write geometric proofs, I suggest that investigations be done in determining if a teacher's level of content knowledge aids or inhibits the students' capability to perform this difficult task.

Having implemented these ideas and writing assignments into my classroom, I saw an improvement in not only my student ability to write mathematical proofs but also in their attitudes towards writing mathematically. The students enter the year very fearful of the proof writing process but by making writing a common aspect of the class, the students will become comfortable with articulating their thoughts, using their mathematical vocabulary, and explaining their ideas through proof. If we as teachers can eliminate fear and allow are students ample opportunities to learn and practice writing, we can change the attitudes related to proof writing.

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# APPENDIX A
# SAMPLE PROOF TEST

# Geometry Honors: Proofs Test
# Mrs. McAllister

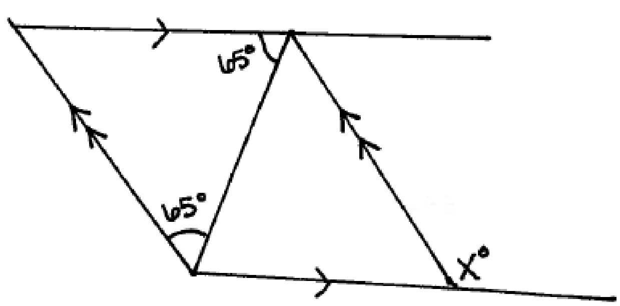
Name:_______________________________________________ Date:____________________

*Directions: Use the given information and your knowledge of mathematics and proof technique to complete the following. In each problem you will need to give complete mathematics explanations and justifications for your proofs.*

1. **There are 36 sophomore boys who are either on the football team, baseball team or both teams at Parkview. You know 15 sophomore boys are on the football team only and 8 sophomore boys are on both the football team and the baseball team. Prove how many sophomore boys are on only the baseball team.**

2. **Prove that if two lines intersect, then vertical angles are congruent using the linear pair postulate.**

3. **Find the value of *x* in the figure and write a proof for its value.**



## APPENDIX B
## SAMPLE EXPOSITORY WRITING ASSIGNMENT ANSWER

**If a 56 inch boards is cut into two parts such that the first piece is 8 more than 3 times the second, find the length of each piece.**

We must determine the length of two pieces of board whose total is 56 inches and the first piece is 8 more than 3 times the second. To solve this, we must define our variable and set up a linear equation with the given information. Let x be the length of the second piece of board. Then the length of the first piece of board is equal to $3x + 8$. The total of the two pieces is 56 inches, we can write the equation $x + 3x + 8 = 56$. By combining like terms we get $4x + 8 = 56$. Next, we subtract 8 from each side by the subtraction property of equality to get $4x = 48$. Then, we divide both sides by 4 by the division property of equality to obtain $x = 12$. Since x was the length of the second board, we know that its length is 12 inches. By subtracting 12 from our total of 56, we know that the first piece is 44 inches. Therefore, one piece is 44 inches and the other is 12 inches.

## APPENDIX C
## SAMPLE EXPOSITORY WRITING ASSIGNMENTS

**<u>Assignment #1:</u> How to Make a Peanut Butter and Jelly Sandwich**
You must write a complete and thorough explanation of how to make a peanut butter and jelly sandwich. You should assume the person you are giving the directions to has never done this before and tell them everything they need to know.

**<u>Assignment #2:</u>** If a 56 inch boards is cut into two parts such that the first piece is 8 more than 3 times the second, find the length of each piece.

**<u>Assignment #3:</u>** A 60-inch piece of string is cut into two pieces. The first piece is 6 inches longer than twice the second piece. Find the length of each piece.

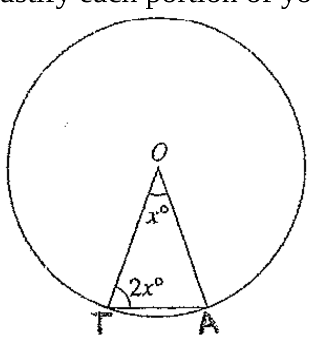
**<u>Assignment #4:</u>** Two angles are complementary. One contains 30 degrees more than the other. Find both angles.

**<u>Assignment #5:</u>** Abby took 2 hours longer to drive 360 miles on the first day of a trip than she took to drive 270 miles on the second day. If her speed was the same on both days, what was the driving time each day?

**<u>Assignment #6:</u>** The base of an isosceles triangle is 5m less than 4 times the length of a side. The perimeter is 67m. Find the length of each side and the base.

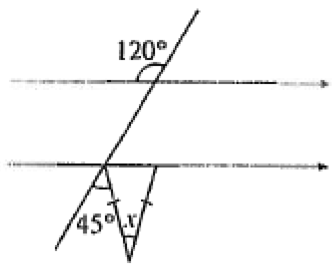
**<u>Assignment #7:</u>** $\overline{KL}$ is a segment representing one side of an isosceles right triangle KLM, with K(2,6), and L(4,2). $<$ KLM is a right angle, and $\overline{KL} \cong \overline{LM}$. Describe how to find the coordinates of vertex M and name these coordinates.

**<u>Assignment #8:</u>** O is the center of the circle. Form an equation in x and solve the equation. Justify each portion of your equation with geometric theorems and/or facts.



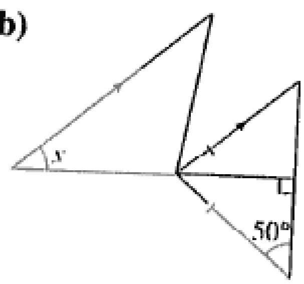
**Assignment #9:** Form an equation for x and solve for x. Justify each portion of your equation with geometric theorems and/or facts. (Page 320 #10a)

(a)

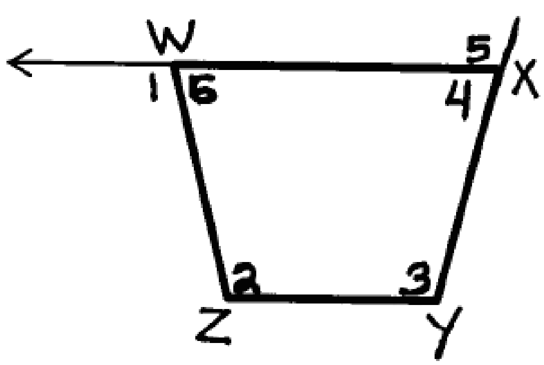



**Assignment #10:** Form an equation for x and solve for x. Justify each portion of your equation with geometric theorems and/or facts. (Page 320 #10b)

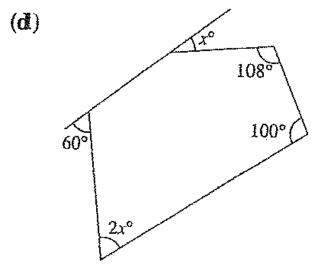
(b)



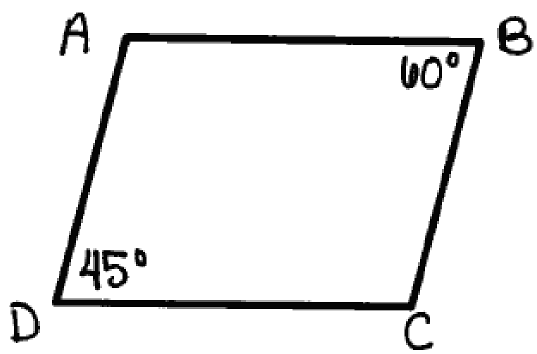

**Assignment #11:** Explain why you can conclude that < 2 and < 6 are supplementary, but you cannot state that < 4 and < 6 are necessarily supplementary.



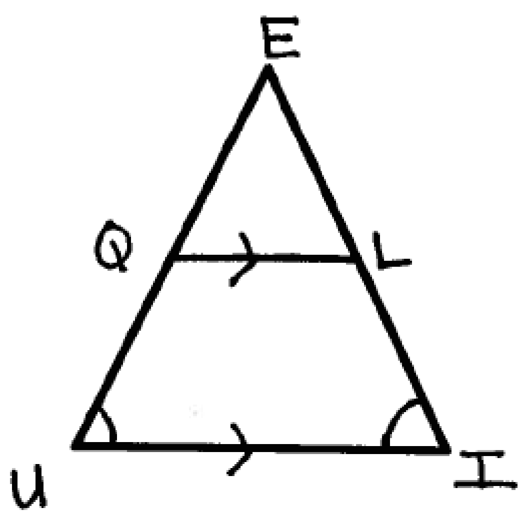
**Assignment #12:** Form an equation in x and solve the equation.
(New Elementary Mathematics 1 Syllabus D page 275 d)



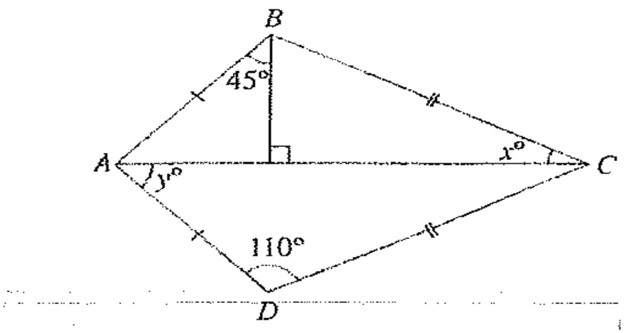

**Assignment #13:** Given the figure ABCD, with $\overline{AB} \parallel \overline{DC}$, $m < B = 60°, m < D = 45°, \overline{BC} = 8, \& \overline{AB} = 24$, find the perimeter.




**Assignment #14:** Write a two-column proof to prove that ΔEQL is equiangular.



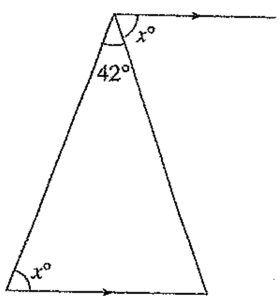
**Assignment #15:** ABCD is a kite. Find the values of x and y. Justify each portion of your equation with geometric theorems and/or facts.




*ABCD* is a kite.

**Assignment #16:** Form an equation in x and solve the equation.
(New Elementary Mathematics 1 Syllabus D Page 265 j)

**(j)**




**Assignment #17:** A helicopter hovers 700 feet above a small island. The figure shows that the angle of depression from the helicopter to point P is 36 degrees. How far off the coast to the nearest foot, is the island?

## APPENDIX D
## SAMPLE JOURNAL QUESTIONS

- What does writing in mathematics mean to you?

- What was your initial impression of proofs and the proof test? How did they make you feel?

- What is a proof in your own words? (How would you explain it to your grandmother?)

- From the framework, rubric, and example, what did you specifically learn about expository writing assignments and what will you keep in mind as you do them this year.

- What experience do you have writing in Math class prior to this year? If you have done any, what types of writing assignments have you done? Please give good examples and details. Were you taught how to write in math and about using good mathematical vocabulary, etc. If you have not ever written in math, do you think it would have made the assignments we are doing easier and why or why not.

- How well do you feel you understood the concept discussed in class yesterday and how could you better your understanding?

- How did you feel about writing triangles congruence proofs? What caused your problems? What could have bettered your understanding?

- How do you feel about writing proofs involving polygon properties?

- As we prepare to write proofs about circle properties, what should you remind yourself about that you learned first semester in regards to writing a proof well?

- What anxieties do you still have about proofs and how do you feel you could overcome them?

- What similarities are there in writing triangle congruence proofs and triangle similarity proofs?

- In what ways, do you see yourself using mathematics in your future?

- Why do you believe we write proofs in high school Geometry?

- What is your favorite concept in mathematics and why?

- In what ways, can you use geometry in your daily life? Give specific examples.

**APPENDIX E**
**IRB FORMS**

## Application for Exemption from Institutional Oversight

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.

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

-- 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:** Amanda McAllister **Rank:** graduate Student

**Dept:** math/mns/Lamsti **Ph:** 225-205-9449 **E-mail:** amandachoppinmcallister@gmail.com

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

Dr. James Madden Professor
madden@math.lsu.edu
225-578-3525

IRB# E5563 LSU Proposal #

⊗ Complete Application

Ⓝ Human Subjects Training

**3) Project Title:** Using writing assignments in High School Geometry to improve Proof Writing Skills

**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: 7-17-2014

**4) Proposal? (yes or 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 in the school I work in

*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** Amanda McAllister **Date** 6/30/2011 (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** [signature] **Date** 7/18/11

## Parental Permission Form

**Project Title:** **"Using writing assignments in high school geometry to improve proof writing skills"**

Performance Site: Parkview Baptist High School

Investigators: Amanda McAllister
Parkview Baptist Math Department Faculty
Master's of Natural Science Degree Candidate at Louisiana State University
225-205-9449

Purpose of the Study: To improve students' proof writing ability and ability to communicate mathematically through increased writing opportunities in high school geometry.

Inclusion Criteria: All Honors Geometry students during the 2011-2012 school year

Exclusion Criteria: None

Description of the Study: Many high school math students never have had experience with writing in mathematics until they reach Geometry and are expected to write proofs. This causes many students great difficulty and anxiety because they are unable to communicate their mathematical ideas through writing. As a means to improve the students' mathematical writing skills, I will assign things such as journal writings, written explanations to word problems, etc. Theses assignments will be built in as part of the Honors Geometry curriculum and done throughout the school year and graded for completeness or correctness depending on the type of assignment. The results of their experience with writing and how it improved throughout the year will be analyzed and used for future reference in the mathematical education community.

Benefits: The goal of this study is to improve students' ability to write proofs and communicate mathematically as well as their comfort level with these types of tasks.

Risks: There are no known risks.

Right to Refuse: All students will be assigned the same material and grades used during the school year. Participation in the study results is voluntary. In this case, grades will be counted as with all students but data not used in results. A student will have the right to withdraw or a student's parent will have the right to withdraw their student from the study at any time without penalty.

Privacy: Results of the study may be published, but no names or identifying information will be included for publication. Subject identity will remain confidential unless disclosure is required by law.

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 of my questions have been answered. I 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. Matthews, Chairman, Institutional 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 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:**__________________

**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:** 7-17-2014

**Child Assent Form**

I, ________________________________, agree to be in a study to improve mathematical communication and proof writing ability through the use of writing assignments such as journal writings, written explanations to word problems and other various writing opportunities. I can decide to withdraw from the study at any time without getting in trouble but I understand in this case my grades will still be used for my Geometry course but my results and improvements will not be documented in the study data.

**Child's 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
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225-578-8692 I www.lsu.edu/irb
**Exemption Expires:** 7-17-2014

## VITA

Amanda Choppin McAllister was born in Baton Rouge, Louisiana to Geoffrey and Beverly Choppin. She is married to Jason McAllister and has one daughter, Catherine. She received a Bachelor's of Science in Mathematics, a concentration in secondary education, in May of 2006 from Louisiana State University. After graduation, she taught at Episcopal High School from August 2006-May 2011 and currently teaches at Parkview Baptist School in Baton Rouge, Louisiana.