How Can I Get the Answer If I Don't Understand the Question?: Teaching Mathematics to English Language Learners

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Abstract

English Language Learners are challenged to be successful in content-area classes at the same time that they are learning English; in addition, the State of Ohio requires that these students pass the Ohio Graduation Test (OGT) in order to receive a high school diploma. Many high school English Language Learners lack the academic English needed to achieve success on the mathematics portion of this test. The purpose of this study was to determine whether or not explicit instruction in the vocabulary and language of mathematics for these students would result in their achieving proficiency on the OGT. During the seven weeks prior to the October 2008 test administration, I incorporated specific vocabulary and language strategies into mathematics instruction for a group of English Language Learners; I compared their scores on the October 2008 test with their scores on the March 2008 test. Although my students did not achieve proficiency on the October test, results of the study indicated that explicit vocabulary and language instruction did result in higher test scores for those students.

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Introduction

Many of our English Language Learners (ELLs) arrive in our schools having had interrupted schooling or little or no formal schooling; they may know little mathematics beyond addition, subtraction, multiplication and division. They are unable to work "word problems" because they do not understand the language of math (Campbell, Adams & Davis, 2007). If they are at least fifteen years old, they are placed in high school regardless of their academic backgrounds. At the same time that they are learning English, these students are enrolled in high school level classes in math, science and social studies, with the expectation that they will graduate in four or five years. No Child Left Behind set the goal that 100% of the nation's students will be proficient in reading and mathematics by the year 2014. Ohio has responded to this challenge by instituting, among other standards, a mandatory graduation test in five subjects: reading, mathematics, writing, science and social studies.

The Westerville City School District**,** located just northeast of Columbus, has experienced rapid growth in recent years, especially in the area of English Language Learners, where numbers quadrupled during the four years from 2002-03 to 2006-07. The district has expanded its English as a Second Language (ESL) program at all levels to address the growing need for English language instruction, but has no formal program to address the content area needs of our ELL high school students in mathematics. Next year (2009-10), the ELL subgroup will be large enough to be "reported"; thus, their performance as a group will have an effect on the school's report card and Adequate Yearly Progress (AYP) status. Also, ELL students may be included in the "ethnic minority" and "economically disadvantaged" subgroups, and a few are also labeled as "students with disabilities." Thus, ELL student scores will impact the school's report card in multiple areas.

At Westerville South High School we have a significant number of ELL juniors and seniors who have yet to pass the Ohio Graduation Test in mathematics. We have many more students in all four grades who are earning poor grades in math despite their best efforts. As an ESL teacher who is also licensed to teach mathematics, I teach classes designed to help ELL students prepare for the Ohio Graduation Tests (OGT) in reading, writing, and mathematics. Many students have come to me for help; they do not understand the language of mathematics. They are unable to translate the words into the symbols and the procedures needed to work the problems. Many general education classroom teachers feel that they are unprepared to bridge this math language gap.

During the fall semester 2008, I was assigned a small group of ELL juniors and seniors (3 girls, 2 boys; 2 Hispanic, 3 Somali) who had yet to pass the OGT Mathematics Test. These students were enrolled concurrently in a year-long math class, either Integrated (Algebra and Geometry) A or Integrated B. Four of the students had taken the test at least once; the fifth student was a junior from Mexico who had just enrolled at Westerville South and had not taken the test.

The OGT is a high-stakes test: students must pass the test to earn a diploma, and students' performance on this test impacts the school district's state report card. I look for ways to provide additional help for my struggling students. If I teach them explicit vocabulary and reading strategies, will they improve their performance on the Ohio Graduation Test in Mathematics? This question served as the basis of my action research conducted between September 2008 and January 2009.

From the experts

When I began reviewing the existing literature, I was surprised to learn that the language-math connection had been under scrutiny since the 1980s. Passage of the No Child Left Behind Act of 2001 led to an increase in the research in this area because the mandate that all students will become proficient in reading and mathematics includes English Language Learners.

Literature on the subject of mathematical literacy for English Language Learners can be divided into two categories: (1) the relationship between English language proficiency and mathematics performance and (2) methods and strategies that teachers may employ to help ELLs learn the language needed for success in mathematics.

The Relationship between English Language Proficiency and Math Performance

The first category is composed predominantly of studies involving standardized tests. Many of these studies compare the performance of English Language Learners on the standard versions of the tests to their performance on linguistically modified versions of the test (Abedi & Lord, 2001; Hofstetter, 2003; Kiplinger, Haug & Abedi, 2000). Results of these studies have been that, in general, ELLs perform better on linguistically modified versions of the test items. Abedi and Lord (2001) found that ELLs in low level math classes benefited more from language modifications than students in higher level classes and that those from lower socioeconomic backgrounds benefited the most. Hofstetter's (2003) study, conducted with students whose first language was Spanish, found that student performance on mathematics tests is best when the language of the test is the same as that of math instruction. Students whose first language is Spanish performed better on an English linguistically modified test than on the Spanish version if the language of instruction was English. Kiplinger et al. (2000) found that the students performed best when a glossary was included on the test.

Improving Math Performance in ELLs

The second body of literature, suggested methods and strategies for teaching ELLs, has increased rapidly since the mandate of No Child Left Behind. Echevarria, Vogt and Short (2004), creators of the Sheltered Instruction Observation Protocol (SIOP) method of instruction for ELLs, have led the field in developing a program that incorporates both content and language objectives into teacher units and lessons. The SIOP method is being used in programs throughout the United States. SIOP is based on the premise that "language acquisition is enhanced through meaningful use and interaction." Development of students' academic language is a consistent part of the teacher's lessons (Echevarria, Vogt & Short, 2004).

Students need to have a strong command of both social, everyday language and specialized mathematical language in order to have full access to the mathematics content of texts, lessons and assessments. ELLs have a particular challenge in that they are working toward English language proficiency and adapting to American culture at the same time that they are learning new mathematics content taught in English (Buchanan & Helman, 1993; Cuevas, 1984; Hudson, Miller & Butler, 2006; Lager, 2006). Hudson, Miller and Butler (2006) define "explicit teaching" and outline an instructional sequence that has been successful in teaching math to ELLs and other students having difficulty with mathematics. Specific strategies are outlined in several other works; for example, visual aids such as word walls, drawings and pictures (Furner, Yaiiya & Duffy, 2005; Harmon, Hedrick & Wood, 2005), vocabulary cards and word sorts (Carter & Dean, 2006; Lee & Herner-Patnode, 2007), realia and manipulatives (Hudson et al., 2006; Furner et al., 2005; Lee & Herner-Patnode, 2007), and graphic organizers (Adams, 2003; Carter & Dean, 2006; Harmon, et al., 2005; Lee & Herner-Patnode, 2007).

For my study of the effect of explicit language instruction on mathematics performance, I decided to follow the explicit instruction sequence described by Hudson et al. (2006), while incorporating language objectives and many of the specific strategies listed above. Explicit teaching is a structured approach that begins with the teacher activating students' prior knowledge and connecting that knowledge to the upcoming lesson. This is followed by teacher demonstration, guided practice, and finally, independent practice. Researchers have found that incorporating the use of direct instruction into the teaching of students who are having difficulty with the basics of math is more effective than using only student-centered instructional methods (Hudson et al., 2006).

Procedures

Instructional Planning

When I was assigned to teach a semester class to prepare low-performing ELL students for the Ohio Graduation Test in mathematics, I looked up their scores from the March 2008 administration of the test. Scrutinizing the subscores on the five standards tested (number sense, measurement, geometry, algebra and data analysis), I looked for areas of strength and weakness within the group. There were ten juniors and seniors who had not yet earned a "proficient" rating on the OGT. Although as a group the students were weak in all areas, the scores on the geometry and data analysis sections were especially low. For example, on the geometry subsection, only two of the ten students scored two or more points out of a possible eight.

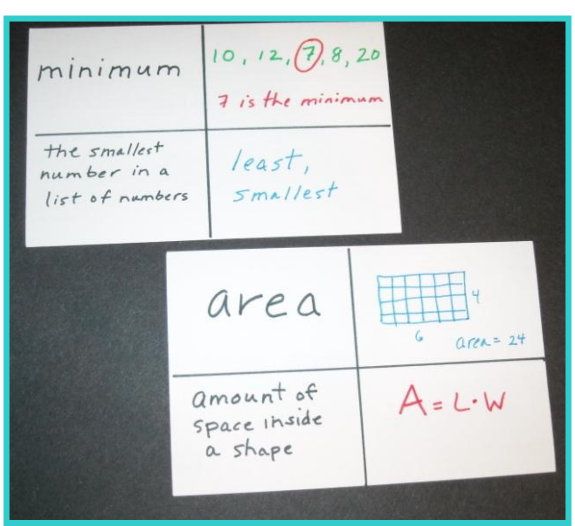
When the school year began, I learned that due to scheduling conflicts, only five students were registered for the class, not ten, as I had thought. One of the students was new to the United States, so I had no scores from the March 2008 test administration to use for comparison. In spite of my disappointment, I decided to go through with the project with the four remaining students. The scores on the March 2008 test were low: on a scale on which 400 is "proficient," my students had earned scores of 351, 361, 361 and 381. These scores indicated that they earned raw scores of 6 to 13.5 points out of a possible 46. To achieve a score of 400, a student needed to earn a raw score of 19.5 points.

I had only seven weeks of instruction before the October 2008 administration of the test, so I decided that, although I needed to cover all five standards within that time, I would concentrate my efforts in the explicit teaching of the vocabulary and language of mathematics on geometry and data analysis, the two areas in which the previous scores were the lowest. I would use what I know to be "best practices" in the teaching of math in the instruction in all five areas. I collected OGT preparation books and materials from my school, from my private library, and from the Ohio Department of Education website. Before classes resumed in the fall, I pored over these materials to choose those that I felt would benefit my students the most as they prepared to retake the OGT. Having selected the math content, I referred to the literature and to the materials in my personal files to choose ways to apply the strategies that I planned to use to teach the vocabulary and language of the selected math topics. I planned to spend one week each on number sense, measurement, and algebra and two weeks each on geometry and data analysis.

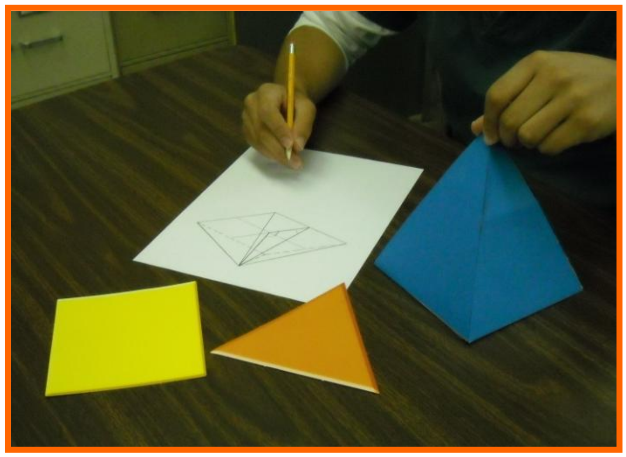
Vocabulary Interventions

Since the purpose of my class was to prepare students for the OGT, I needed to address all five standards on which students were to be tested. Therefore, the students received some vocabulary instruction in number sense, measurement, and algebra as a part of best practices, but the selected vocabulary interventions were reserved for instruction in geometry and data analysis. My regular instructional techniques included listing the key vocabulary for the students to study, using the correct vocabulary during instruction, reviewing key terms daily, and monitoring student talk to help them use the correct terms as they explained how they worked problems. I began instruction with number sense and measurement because much of content of these standards is incorporated into the problems students encounter within the other standards.

Next I taught geometry, where I began introducing explicit vocabulary and language instruction. Geometry has an extensive and specialized vocabulary. I concentrated my effort on the vocabulary associated with two-dimensional and three-dimensional shapes, angles and lines, because these topics are represented in several problems on the OGT. Pretesting indicated that students could not identify most shapes. They confused "triangle" with "rectangle," and named most four-sided figures "squares." They knew "area" only as "length times width" and did not know the meaning of the word "perimeter," even though these topics had been presented in their previous math courses. At this point, we began to put new or difficult vocabulary on a word wall. Word walls are useful in displaying content words; the words are readily available for students to refer to throughout the unit (Echevarria, et. al., 2004). I wrote each new term on a 4 x 6 index card and put it on our word wall, which I placed so that students could see it easily from their seats.



I gave each student several 5 x 8 index cards to make 4-square vocabulary cards for any word that he or she found particularly troublesome. Each index card was divided into four sections. The upper left section contained the word; the upper right displayed a drawing or example. The lower left corner held the definition, and the lower right was for the formula (if applicable), another example or something else that the student felt would help him remember the word. Students self-selected words, but I suggested words for students as instruction progressed. Each day at the beginning of class, students read over their cards; at the end of class they created additional vocabulary cards as needed. When a student had difficulty with a word during class, I referred him to his vocabulary cards. I encouraged students to work with a few words at a time; English learners may be easily overwhelmed if they think they have to learn a long list of words. I have found that if I give them too many cards, they are likely to become discouraged and not use them at all.



Cardboard two-dimensional shapes, wooden three-dimensional shapes and nets for these shapes were on display and available for students to use as they deciphered problems involving the perimeter, area, and volume of shapes. Handling these figures helped the students visualize problems, making the two-dimensional diagrams given as part of many problems easier to decipher. For example, picking up the square pyramid and examining its base helped students visualize the two-dimensional drawing of a square pyramid. I also required students to draw a diagram or picture for each problem involving shapes. At first some of them argued, “I can’t draw!” but I persisted, teaching them how to draw specific shapes, and their drawings became better. They realized that a drawing was an essential piece in the solution to the problem. I began creating graphic organizers to help students sort and order the information given in word problems.

Diagrams were an essential part of our work with lines and angles. Every problem required that students either decipher the given diagram or create their own drawing. I created angles and sets of lines out of tag board and paper fasteners. Students could manipulate these to illustrate various angle relationships. Students also created 12 x 18 drawings of angle relationships which I posted on the wall at the front of the classroom. Hands-on learning materials and the use of manipulatives help English learners connect abstract concepts with concrete experiences (Echevarria, et.al, 2004).

Most of the data analysis questions on the OGT have to do with reading and interpreting graphs and determining probabilities. Students were used to seeing graphs in science and social studies textbooks. They all knew what a bar graph was but were unfamiliar with the word “histogram.” They knew a circle graph but were uncertain about the term “pie chart.” They could pick out the smallest and largest entries on a graph and identify increasing or decreasing trends but had trouble answering questions that required them to add or subtract values displayed in the graph. Names for the types of graphs, “frequency,” “value” and “axis” were added to the word wall and to students’ 4-square vocabulary cards. As students constructed their own graphs from simple data sets, they gained insight as to how a graph actually represents the given data

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Probability was confusing for all of my students. I have found that probability is an obstacle for even those students who come to the U.S. with strong math backgrounds. In many countries probability is not taught as part of the pre-college math curriculum. American high school texts teach probability using examples of coin tosses, rolling dice and drawing cards. My students had no experience with dice and cards; they had no idea what these problems meant. They had been given a definition of probability in the form of a fraction, but the problem may ask for the answer as a percentage. The students simply did not understand the vocabulary or the concept.

The pretest on probability showed almost no prior knowledge, so I began instruction at the beginning with the definition of "probability." The students readily admitted that they did not understand probability and were concerned because they knew that probability problems would be part of the OGT. This was the one topic on which we were starting from the very beginning. They referred to the word wall and to their vocabulary cards often. We used manipulatives throughout the lessons – coins, dice, cards, spinners, counters; students worked through problems using the actual objects. I gave them a framework for recording results as they worked through a problem to help keep their work organized. Problems that did not lend themselves to these manipulatives were often able to be solved using drawings or tree diagrams. Throughout this hands-on problem solving, students were required to use the correct vocabulary. At the end of probability instruction I could tell that they were much more comfortable with the topic. They were able to solve simple problems and explain how they got the answers.

I addressed the algebra standard last because I knew that this was currently being covered in their mainstream math classes. Again, I limited my vocabulary instruction to best practices mentioned at the beginning of this section.

Data Collection

The purpose of my study was to determine whether or not explicit instruction in vocabulary and the language of mathematics would result in an increase in students' OGT math scores, I obtained the students' scores from the March 2008 test administration by examining the school records for each student. These are put on file as soon as they are received from the Ohio Department of Education. I obtained the results of the October 2008 test administration in January 2009.

I gave students pretests to ascertain their prior knowledge of both the vocabulary and the math skills needed for successful performance on each standard; I used this information to inform instruction. I gave post-tests to help determine the effectiveness of my instruction, but the ultimate determination was the results of the October 2008 OGT.

Results of the Study

When I received the students' scores from the October 2008 administration of the OGT, I was disappointed, but not surprised, to learn that none of the four students had earned the necessary score to be "proficient." However, the overall score for each student increased by 10 – 22 points; the range of scores went from 351 - 381 in the spring to 361 – 396 in the fall. [Figure 1] Of greatest interest to me was that these increases were primarily due to a marked increase in the subscores for geometry and data analysis. For geometry, the range increased from 0 – 2 points out of a possible 8 to 2 – 5 out of 8. [Figure 2] The increase in the data analysis scores was even greater: from 0 – 1 out of a possible 11 to 1 – 5 out of 11. [Figure 3] I was quite pleased with these scores, especially when I compared them to the subscores for the other three standards.

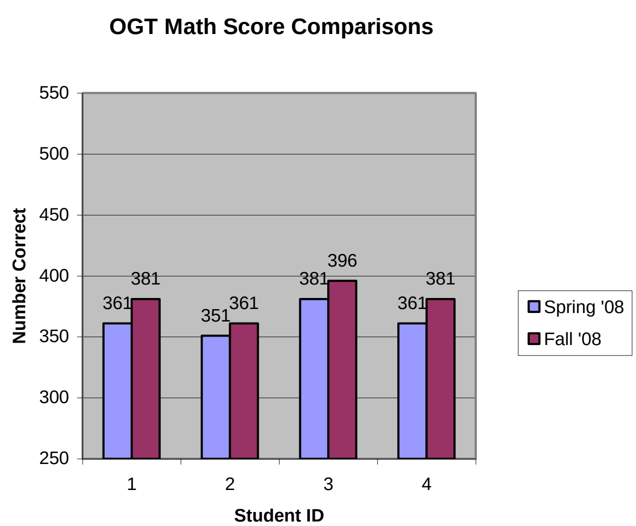

Figure 1

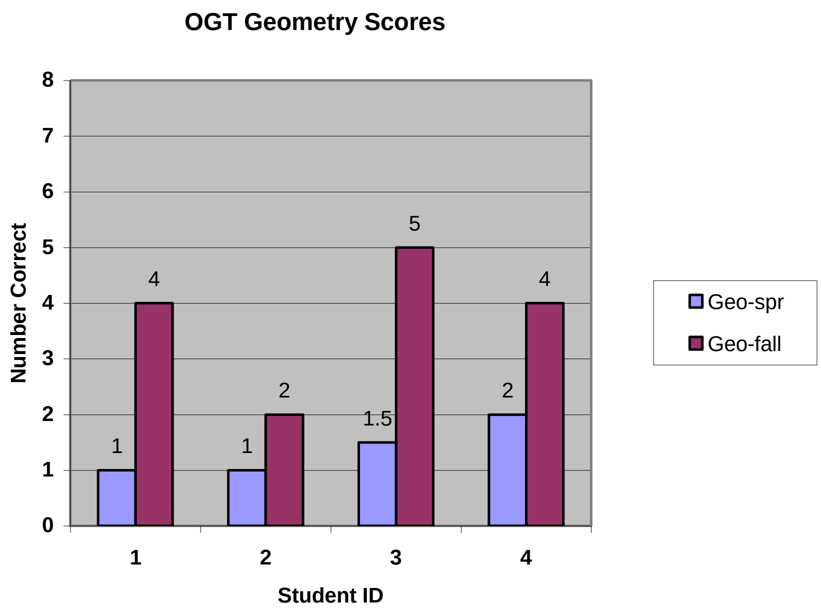

Figure 2

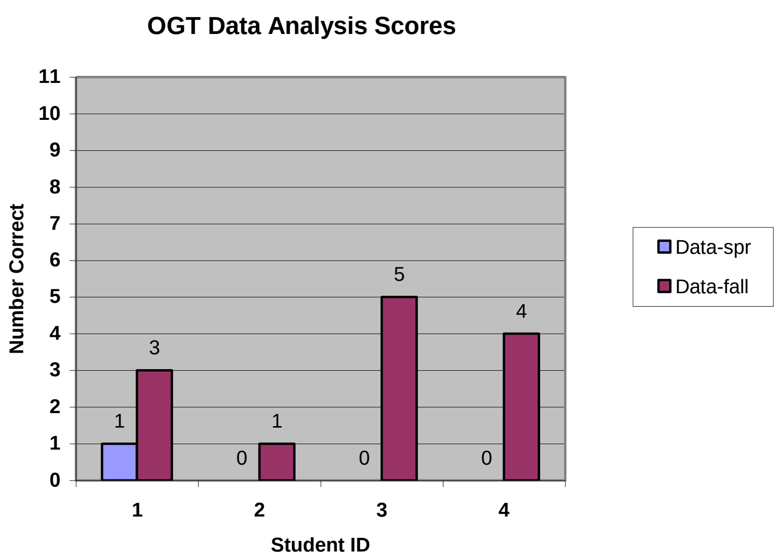

Figure 3

The scores for number sense [Figure 4], measurement [Figure 5] and algebra [Figure 6] showed no marked increases; scores in each area showed little increase and in several cases, actually decreased. Two students' scores in number sense increased by 0.5 points and one student's algebra score increased by 2 points; all other subscores remained the same or declined. I cannot explain why scores did not increase; I had anticipated at least a small increase simply because the students were receiving math instruction for two class periods each day prior to the OGT – one period in their mainstream class and a second period in my small ESL class.

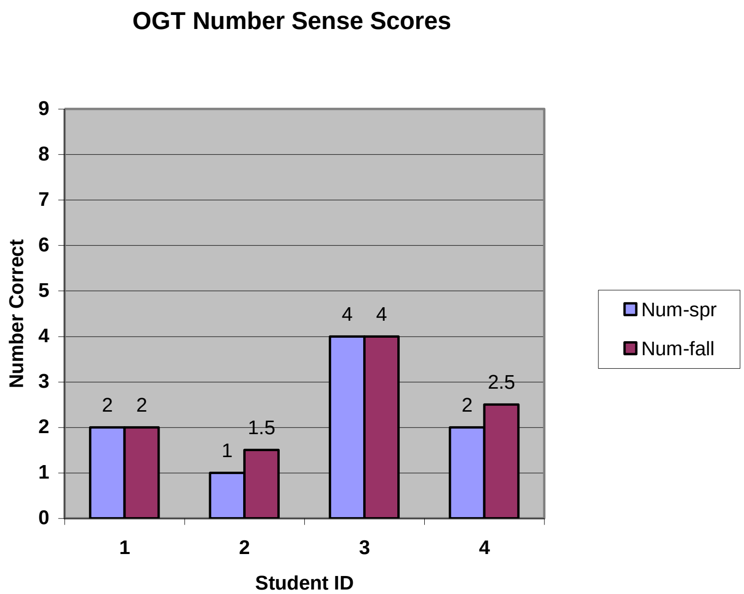

Figure 4

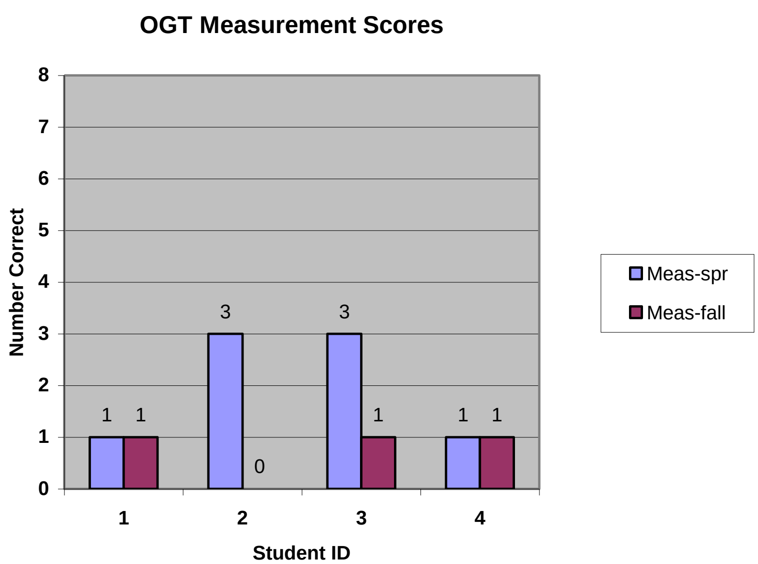

Figure 5

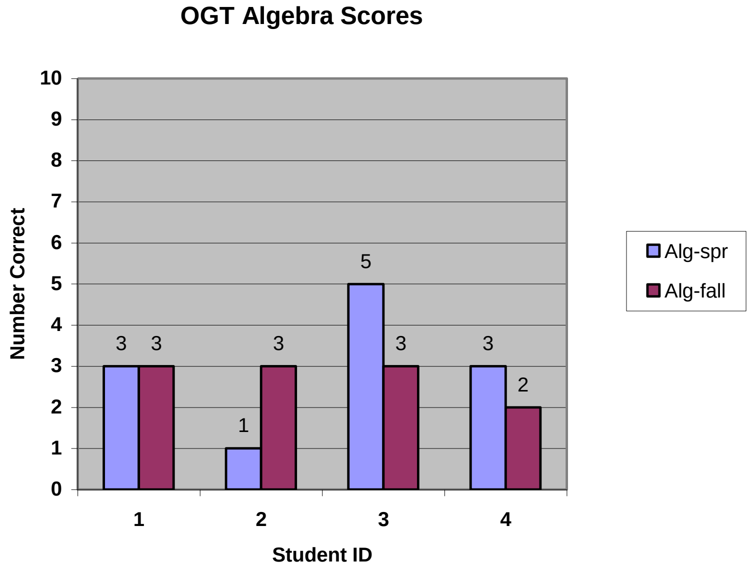

Figure 6

Reflections

On the one hand, I was disappointed that even with explicit vocabulary instruction, none of the students passed the test. On the other hand, I was encouraged by improvement in student performance on the geometry and data analysis portions of the test. On the data analysis section on the March 2008 test, three of the four students had gotten no items correct. On the October 2008 test, three of the four students got at least 30% correct. On the geometry section, two students had only one item correct in March, but three of the four students answered at least 50% of the items correctly in October.

Although the results of the study showed a marked increase in scores following language intervention, I cannot draw conclusions based on one small sample. It is possible that the increase in scores was a result of the additional instruction in mathematics content. However, I do believe that vocabulary and language instruction influenced the test scores because subscores improved greatly in geometry and data analysis, the areas in which I incorporated explicit language instruction. Subscores did not improve in the other three areas although students received additional mathematics instruction in those areas.

It does appear that my results support the research of Hudson et al. (2006) and Echevarria et al. (2004). Hudson et al. (2006) found that a direct instruction approach (explicit teaching) benefitted students who were having difficulty with math. Echevarria et al. (2004) incorporated language objectives into content area teaching. I combined the explicit teaching of language with the teaching of mathematics content. Although this research project had very positive results, I need to continue using vocabulary and reading strategies in mathematics instruction to see if language instruction continues to result in higher scores on the OGT Mathematics Test.

Next year I will have a new group of students who will take a different test. I will incorporate explicit vocabulary and language instruction into my teaching of all five standards tested. I believe that such instruction will lead to higher scores on the OGT math test because the students will have a better understanding of what they are being asked to do. If my English Language Learners do achieve a higher passing rate on the OGT, other teachers whose students are struggling to pass sections of the OGT may want to add explicit language instruction to their own lessons.

In the past, high school teachers just assumed that students were able to read the textbook and other course materials and that if students just studied hard enough, they would be able to pass. Our efforts to comply with the mandate of No Child Left Behind should indicate to us that merely "studying harder" is not enough. Teachers of core content classes feel pressured to "cover the curriculum" and don't feel that they have time to devote to language instruction. I hope to be able to demonstrate to my colleagues that time spent on explicit instruction in the vocabulary and language of their disciplines will pay off.

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