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ABSTRACT

This action research project describes a program for improving student comprehension of mathematical vocabulary. The targeted population consisted of two classes of fifth grade students from two elementary schools located in the suburbs of a large metropolitan area in Illinois. The problem of poor mathematical vocabulary was documented through teacher and student surveys and questionnaires, student vocabulary checklists, and teacher observation of students' daily work. Upon analysis of the data with respect to probable causes, it was discovered that students have varied mathematical backgrounds, suffer from math anxiety, and have poor reading comprehension. In addition, expectations of students have shifted due to a change in standards by the National Council of Teachers of Mathematics (NCTM) and on the Illinois Standards Achievement Test (ISAT). Furthermore, it was revealed that the vast majority of math series focus on computational facts rather than mathematical vocabulary. A review of solution strategies proposed by experts in the field, combined with an analysis of the problem setting, led to the following interventions: student math journals, student-created math dictionaries, children's literature to introduce and reinforce mathematical concepts, graphic organizers, visual aids, and written explanations of open-ended word problems. As a result of the aforementioned interventions, the students exhibited an increase in comprehension and use of mathematical vocabulary in math performance and in communication of mathematical ideas. (Contains 45 references.) (Author/ASK)

MATHEMATICS VOCABULARY
AND ITS EFFECT ON STUDENT COMPREHENSION

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DEDICATION

We dedicate this project to our family and friends. Your support and patience is an endless source of strength.

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Upon analysis of the data with respect to probable causes, it was discovered that students have varied mathematical backgrounds, suffer from math anxiety, and have poor reading comprehension. In addition, expectations of students have shifted due to a change in standards by the National Council of Teachers of Mathematics (NCTM) and on the Illinois Standards Achievement Test (ISAT). Furthermore, it was revealed that the vast majority of math series focus on computational facts rather than mathematical vocabulary.

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CHAPTER 1

PROBLEM STATEMENT AND CONTEXT

General Statement of the Problem

Students' poor mathematical vocabulary consistently interferes with academic performance. The fifth grade students of the targeted classes demonstrate a need for increased comprehension of mathematical terminology. Evidence of the existence of this problem includes recent Illinois Standards Achievement Test (ISAT) scores, student performance on tests and quizzes, in-class discussions, daily work, and informal teacher conversations.

Immediate Problem Context

This action research project was conducted in two schools in two different communities. Each setting will be described as Site A and Site B.

Site A is a rapidly growing suburban community located northwest of a large urban community. This unit district serves grades pre-kindergarten through twelve with a projected total enrollment of 3,240 students for the 2000-2001 school year. There are two recently constructed elementary buildings (Pre-K - 3), two intermediate buildings (4 - 5), one middle school (6 - 8), and one high school. The student population consists of 89.8 percent White, 1.6 percent Black, 5.8 percent Hispanic, 2.8 percent Asian - Pacific Islander, and 0.0 percent Native American. Approximately 3.3 percent of the total population is considered low-income. Limited-English-proficient students who are eligible for transitional bilingual education constitute 0.7 percent of the population. Site A has an overall attendance rate of 95.6 percent, with a mobility rate of 16.3 percent. In fifth grade, the average class size is 25.2. The pupil to teacher ratio for the district is 25.3 to 1. The pupil to certified staff ratio is 14.2 to 1, and the pupil to administrator ratio is 225.7 to 1.

At Site A, the total teacher population is 98.4 percent White, 0.0 percent Black, 0.0 percent Hispanic, 1.6 percent Asian-Pacific Islander, and 0.0 percent Native American. The population of teachers consists of 78.6 percent females and 21.4 percent males. The average teacher has 7.9 years of experience and earns an average salary of $33,337. Teachers with Bachelor's degrees make up 77.0 percent of the population, while 23.0 percent have Master's degrees or beyond. The average administrator salary is $72,846 (Illinois State Report Card).

The targeted school in Site A is an older building originally constructed to serve as a high school. The two-story, brick structure now houses both fourth and fifth grades. The staff is organized in grade level teams. Staff members also participate in curriculum committees and serve as integral members of school improvement and internal review teams.

Per week, the fifth grade students of Site A spend an average of 650 minutes in reading and language arts instruction, 300 minutes in math, 150 minutes in science, 150 minutes in social studies, 60 minutes in music, 150 minutes in physical education, and 60 minutes in art. The fifth grade students at Site A are instructed using Saxon Mathematics, an incremental approach in which lessons build on one another. The math curriculum is also supplemented using many problem-solving activities. The students are grouped for math instruction based on ability. Science is divided into four basic units and uses a hands-on approach. The social studies curriculum concentrates on United States history from exploration and Native Americans to the Revolutionary War. For reading, the students read from a basal series by Houghton-Mifflin, which incorporates writing and grammar. Novel units are also used to supplement and enhance the basal. Each classroom has two computers that are Internet accessible, as well as a computer lab in the school for computer instruction. There are after-school extra-curricular activities available to the students as well.

Site B is located in a northwest suburban community. This large unit district serves pre-kindergarten through twelfth grade students. There is one pre-kindergarten building, eight elementary schools, two middle schools, and one high school with a total district enrollment of 7,923 students. Site B has a total enrollment of 507 students. Of the total population of Site B, 74.4 percent of the students are White, 1.4 percent are Black, 11.0 percent are Hispanic, 13.2 percent are Asian-Pacific Islander, and 0.0 percent are Native American. Students from low-income families, families receiving public aid, foster homes supported by public funds, and students eligible to receive free or reduced-fee lunches comprise 2.6 percent of the population. Students with a primary language other than English who are eligible to receive transitional bilingual education comprise 2.2 percent of the student population. The overall attendance rate at Site B is 96.2 percent, with a mobility rate of 9.3 percent. Many more students are moving into the school than are leaving. The average class size for fifth grade is 24.5 students. The average pupil to teacher ratio is 18.8 to 1. The average pupil to certified staff ratio is 14.2 to 1. The average pupil to administrator ratio is 360.1 to 1.

District B employs 478 total certified staff members. Out of the total teacher population, 98 percent are White, 0.3 percent are Black, 1.0 percent are Hispanic, 0.6 percent are Asian-Pacific Islander, and 0.0 percent are Native American. Females account for 69.4 percent of the teaching staff, and males account for 30.6 percent. The average teacher has 15.4 years of experience. The majority of teachers in District B have advanced degrees, with 63.3 percent having a Master's degree or above and 36.7 percent having a Bachelor's degree. The average teacher salary in District B is $56,920, and the average administrator salary is $97,028 (Illinois State Report Card).

Site B is housed in a brick building constructed in late 1998. A courtyard with a fountain and various plants greets students, staff, parents, and teachers from the center of the school as they enter the building. A large multi-purpose room serves as the cafeteria as well as a place for concerts and assemblies. Each grade level is contained in its own "pod," a separate wing branching off of the main hallway. Each "pod" has a central multi-purpose area, which can be accessed and utilized by all classrooms by opening up and folding in the classroom walls. The walls between classrooms can also be opened up to allow for interaction among students in each grade level.

On average, per week, students in fifth grade spend 650 minutes on language arts and reading, 250 minutes on mathematics, 240 minutes on social studies, 200 minutes on science, 100 minutes on health, 30 minutes on computer, 50 minutes in art, music, and media center, and 100 minutes in physical education. Students in fifth grade read from an anthology reading series as well as novels. There is no formal grammar program. Social studies involves the study of world geography. Science is studied using a hands-on approach. Students learn basic keyboarding and typing skills in computer. Mathematics consists of two different programs. One program is hands-on, discovery-oriented. The lessons spiral upon each other and cannot be completed out of sequence. The other program is composed of several primarily teacher-directed units. The lessons in each unit generally build upon each other, but the units can be completed in any order. Teachers in fifth grade primarily instruct using the teacher-directed units, although they do supplement using the discovery program.

Surrounding Community

The targeted school from Site A draws its students from one main community. The early 1990's were rapid growth years for this community and had resulted in several referenda passed in order to build new schools. Even with the rapid growth, the community is still trying to maintain a hometown atmosphere. In 1998 the reported population was 20,637 with a median home value of $153,000. The average income per household is $62,319. Of the homes in this community 93.9 percent are single-family units and 6.1 percent are multifamily units. The median age for this community is 33 years. Its residents have completed an average of 13.4 years of school (www.chicagotribune.com).

The district in Site A has an equalized assessed valuation per pupil of $97,927. The instructional expenditure per pupil is $2,779 and an operating expenditure per pupil of $5,867, for a total of $8,646 spent per pupil (Illinois State Report Card).

Due to the rapid growth of the community, District A has passed several referenda in order to construct new schools. Another referendum will be on the upcoming ballot to allow for yet another school to be built to keep up with the demands of the new-home builders. This provides a challenge to the district in order to hire quality staff. It is projected that there will be approximately 40 new positions available this upcoming school year.

Site B draws students from two surrounding, upwardly mobile, communities. Community One has a population of 3,826. The median home value is $500,001, with homes ranging from $400,000 to $1,000,000. Most homes are two-parent households, with one parent as the primary wage earner. The average median income is $232,987. Commercial development has been kept to a minimum, preserving the countryside. Most homes are built on 2+ acre lots in large subdivisions. A few key businesses are located in the area. There is no central business district or retail center (www.chicagotribune.com).

Community Two has a population of 49,960. The median home value is $152,750. The median family income is $70,407. Residential development has slowed as non-residential development has increased. There is no central business district, but many businesses and large corporations call Community Two home, as it has ragged boundary lines and is split into three far-reaching patches. The increase in business has diversified the population. A majority of the population is White, though roughly 3 percent of the population is Black, 5.7 percent is Hispanic, and 8.0 percent is Asian-Pacific Islander. In addition to residential and non-residential land, Community Two has over 4,000 acres of open space in forest preserve land.

District B has an equalized assessed valuation per pupil of $227,269. It spends $4,884 in instructional expenses and $8,345 in operating expenses per pupil, with a total expense per pupil of $13,229 (Illinois State Report Card).

District B has fought in recent years for the passage of several referenda, with one finally passing in 1997. This referendum resulted in the construction of one new school, the replacement of one existing school with a new building, and the remodeling of several others. Another referendum is on the horizon to complete the remodeling of the remaining district schools. On-going construction at several schools during the school year continues to be challenging for parents, teachers, staff, and students.

Growth and new home-building surrounding Site B continually adds diverse students to the school population. Over 20 new students have started at Site B since the start of the 1999-2000 school year. Debates are on-going in the community over the fates of several available land parcels, whether they be developed as housing or as commercial property, or left as undeveloped land. The diverse student background adds to the challenges of meeting the needs of all students.

National Context of the Problem

The problem of poor mathematical vocabulary has generated concern at the state, national, and global levels. Much of the research on problems students encounter in mathematics courses points to the many language-based misconceptions that students develop. From Australia, Neil Bechervaise (1992) states that students often view mathematics as a foreign language. This view of mathematics as a language helps to explain the many problems encountered by students, including poor mathematical comprehension and their inability to solve problems.

Mary Jo Harris and Evelyn VanDevender (1990) have identified four causes of confusion in mathematics, one of them being vocabulary. A strong vocabulary provides access to mathematical concepts and strategies. Students' understanding of mathematics is dependent on their knowledge not just of the language of mathematics but the language used to teach mathematics as well (Miller, 1993). Even the standards developed by the National Council of Teachers of Mathematics (NCTM) stress the importance of helping students become more comfortable with "math language". With these new standards, it has become a necessity for teachers to teach using "math language" (Moore, 1995). This language of math must be made meaningful in order for students to effectively communicate their understanding of mathematics. Miller goes on to say, "using mathematics vocabulary within a meaningful context should be second nature to mathematics teachers" (1993). Underexposure to mathematical vocabulary and concepts hinders mathematical development and understanding. Students must also be given the opportunity to apply this mathematical knowledge. If students don't "use it", they "lose it".

In 1998, in keeping with the new NCTM standards, the State of Illinois modified the mathematics portion of the Illinois Standards Achievement Test (ISAT) that is given to third, fifth, eight, and tenth graders. The tests now heavily stress the use and comprehension of mathematical vocabulary. Students are asked to solve open-ended problems that require them to write an explanation of "what they did and why they did it". They are graded on three levels: Mathematical Knowledge, Strategic Knowledge, and Written Explanation. In addition to correctly solving the problem, students also need to use the appropriate mathematical terminology in order to be given full credit and meet the state criteria for their grade level. In order to achieve success on the ISAT, students must have a working knowledge of mathematical vocabulary. Illinois teachers have expressed concern as to the best method of instructing their students in this area.

Several researchers have written on the topic of mathematical vocabulary and strategies to improve comprehension. In a report on the use of graphic organizers, Monroe (1998) states:

> The need for rich and meaningful vocabulary knowledge in developing concepts in content areas is documented by research and is generally accepted by classroom teachers (Monroe and Panchyshyn, 1995-1996). Mathematics is recognized as the most difficult content area reading material, "with more concepts per word, per sentence, per paragraph than any other area" (Schell, 1982, p. 544). Because vocabulary represents and provides access to concepts, instruction in the vocabulary of mathematics cannot be incidental. It requires careful attention within the school curriculum (Gawned, 1990). Teachers need

assistance in knowing how to provide meaningful vocabulary instruction in mathematics. (p. 538)

Monroe (1998) concludes that the need for mathematical vocabulary development remains a crucial issue.

JoAnn Gardner (1993) conducted an investigation examining the effectiveness of teaching students the vocabulary of mathematics. Her results indicated that a significant improvement in test scores occurred when students were taught mathematics vocabulary and the definitions that correspond. Libby Krussel (1998) concludes that educators need to bring all students to a fuller understanding of, and appreciation for, the language of mathematics. The understanding of mathematical vocabulary is crucial beyond schooling. According to Krussel (1998), it is not acceptable to be mathematically vulnerable and naïve, to be easy targets for those who use mathematics to manipulate others for their own benefit, including credit card companies, lotteries, and opinion polls. Students need to be aware that mathematical vocabulary is important throughout their lives.

CHAPTER 2

PROBLEM DOCUMENTATION

Problem Evidence

Mathematics has a large, subject specific vocabulary that must be mastered if the concepts in mathematics are to be understood. The need for a strong mathematics vocabulary should therefore be an essential aspect to any mathematics program. However, there is evidence that illustrates the lack of instruction in the area of mathematical terminology.

A variety of tools were implemented to show the evidence of a poor understanding of mathematical vocabulary in the targeted fifth grade classrooms. Evidence was documented through the use of the following: student surveys, student questionnaires, teacher surveys, teacher questionnaires, and math vocabulary checklists.

Student Surveys

To determine attitudes and anxieties about mathematics, the students in the targeted classrooms were surveyed. (Appendix A) A sample of 42 students was asked to rank six statements using the following scale: strongly agree, agree, disagree, and strongly disagree. The data collected in this survey are displayed in Figure 1. For purposes of data comparison and clarity, the categories of strongly agree and agree were combined to show a unified agreement. In addition, the categories of disagree and strongly disagree were also combined to show unified disagreement.

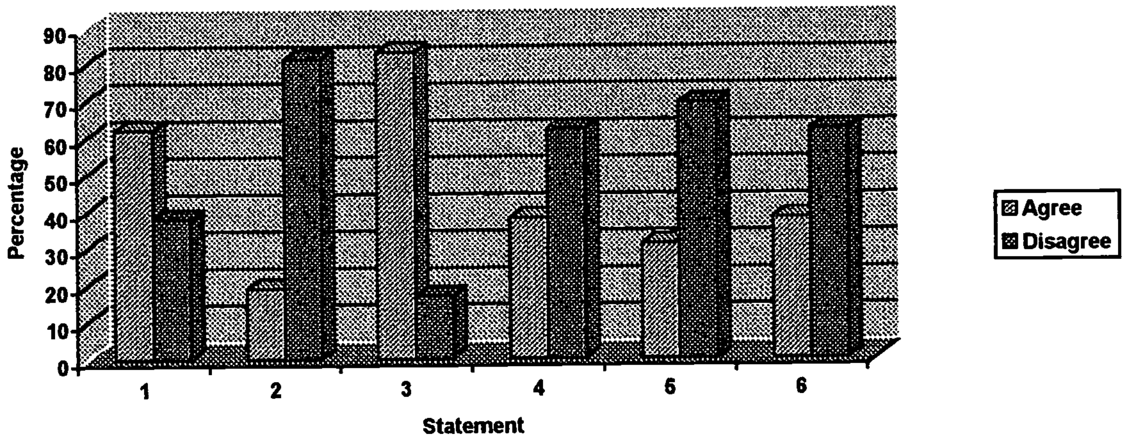

Figure 1. Student survey.

Statement one asked students to agree or disagree with "Math is my favorite subject." A majority of the surveyed students, 62 percent, agreed with this statement to some degree. This correlates with the responses given to statement six, which read, "Sometimes in math I feel nervous, like I can't do the work." The same percentage disagreed with statement six as agreed with statement one. These data suggest that most students feel comfortable with and enjoy math. They do not feel they have any ill feelings or anxiety. However, in response to statement three, 83 percent of the students felt that having a math dictionary would help them with vocabulary they need to know. They feel comfortable in math class, but feel that a dictionary would help them with vocabulary. Responding to statement five, "Math would be easy if I didn't have to read," the majority of students (69 percent) disagreed. This data appears to show that students feel confident in their reading abilities in math class. They do not feel reading affects their abilities. Both statements two and four dealt with students' confidence in solving word problems. In both responses, over 60 percent of the students felt they do not struggle with word problems and do not need help explaining how they solved the open-ended problems. Despite this confidence in their problem-solving abilities, as noted earlier, students feel that a math dictionary would be helpful in their work.

Student Questionnaires

A student questionnaire was developed to investigate prior experiences in mathematics. (Appendix B) The questionnaire also helps to identify students' strengths and weaknesses. Forty-two students were asked to answer five open-ended questions, as well as select from a list of topics that were covered in the previous grade.

Students were asked whether they liked math and to explain why or why not. Twenty-seven out of the 42 students questioned responded yes. Of those who responded yes, they stated the following reasons: fun, easy, challenging, easy to remember, good at it, like it, get good grades, numbers and graphing, solving problems, and it is part of life. Nine students responded no. They had the following reasons: boring, frustrating, confusing, not fun, too hard, always fail, too many tests, homework, and it never works. Six students responded that they sometimes like math. Their responses were a combination of those given by students who do and do not like math. This data is encouraging, as it shows a majority of students enjoy math class.

Students were also asked what helps them understand math better. Of the 24 different responses given, 13 students stated that a more detailed explanation would benefit them. Other top responses include the following: tricks or games (eight students), a good teacher (four students), listening and taking notes (two students), and good books (two students). This suggests that most students want more involvement on the part of their teacher in math class.

When asked what makes math hard, 22 different responses were given. Hard words, hard problems, and big numbers were examples given by 11 students. Eight students cited division and multiplication as being difficult. Five students stated they "just don't get it." One student responded that reading makes math difficult, and one student indicated written explanations make math hard for them. These data show that there are many aspects of math that students find difficult, including vocabulary.

The last open-ended question on the Student Questionnaire asked students what teachers could do to make math easier. Nineteen different responses were given. Fourteen students responded that teachers should explain longer and in more detail. This is in direct correlation to the responses given to the earlier question, "What helps you understand math better?" Students want teachers to focus more time on in-depth explanations of concepts. Six students would like to change word problems in some way, by making the words easier, making the problems shorter, or eliminating them all together. These responses demonstrate that some students recognize they have difficulty comprehending vocabulary and word problems. Six students would like more games to be played in the math class, correlating with the responses given to question three on the questionnaire, "What helps you understand math better?" Students would like their learning in the math class to be more fun.

The final question asked students to circle the topics they covered in math last year. A total of 16 topics were listed. Topics ranged from basic computation to graphing and geometry. The data are presented in Table 1.

Table 1

Student Questionnaire – Mathematics Topics Covered

TOPIC COVERED	# OF STUDENTS	% OF STUDENTS	TOPIC COVERED	# OF STUDENTS	% OF STUDENTS
Addition	40	95	Bar Graphs	39	93
Subtraction	40	95	Line Graphs	41	98
Multiplication	41	98	Circle Graphs	33	79
Division	42	100	Standard Measurement	37	88
Fractions	42	100	Metric Measurement	34	81
Decimals	39	93	Coordinate Graphing	18	43
Probability	16	38	2-D Geometry	22	52
Ratios	14	33	3-D Geometry	22	52

In analyzing the students' responses to this question, the data suggests that students entering the targeted fifth grade classrooms have varied mathematical backgrounds. An overwhelming majority of students have covered basic computational skills, whereas less than fifty percent of the students covered more advanced topics, such as, probability, ratios, and coordinate graphing.

Teacher Surveys

Fourth and fifth grade teachers at the targeted sites were asked to rank six statements on a survey. (Appendix C) The statements covered teachers' feelings and apprehensions about mathematics instruction, as well as their beliefs about students' math performance. Fifteen teachers were asked to rank the six statements according to the following scale: strongly agree, agree, disagree, and strongly disagree. These data are further explained in Figure 2. For purposes of data comparison and clarity, the categories of strongly agree and agree were combined to show a unified agreement. In addition, the categories of disagree and strongly disagree were also combined to show unified disagreement.

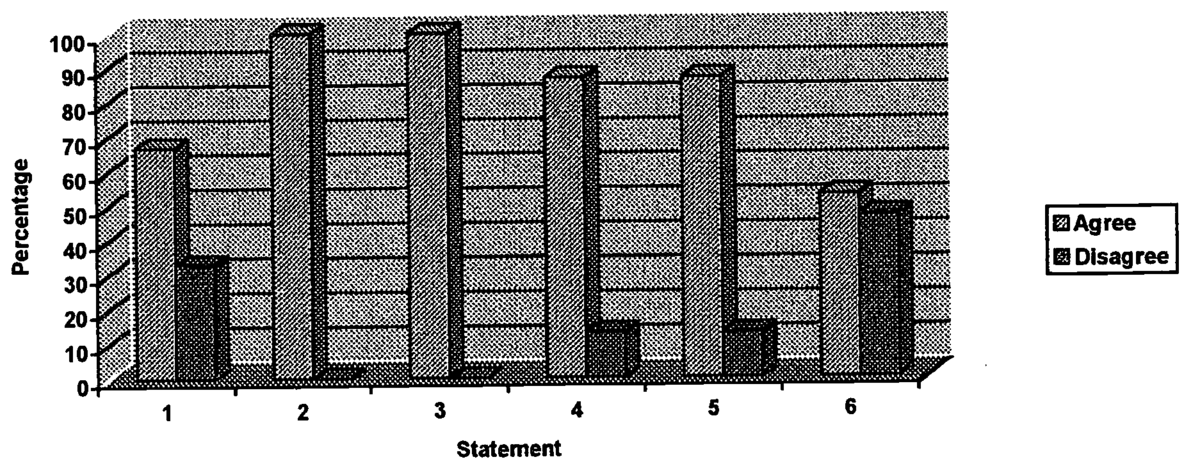

Figure 2. Teacher survey.

In statement one, teachers were asked to rate the following: "I have difficulty in teaching my students how to solve word problems." A majority of the surveyed teachers, 67 percent, agreed. In response to statements two and three, the entire population surveyed agreed that students would greatly benefit from learning the vocabulary of math as well as teachers should use reading comprehension strategies to teach math. Eighty-seven percent of the teachers surveyed agreed with statement four, that students do not understand how to explain their work in an open-ended problem. This is in direct contrast to the students' responses to statements two and four in the Student Survey outlined in Figure 1. The majority of students felt that they did not struggle with word problems nor did they need any help in their explanations to open-ended word problems. In statement five, teachers were asked whether they believed students' math achievement is negatively affected by their lack of understanding of math terms. Over three-fourths (87 percent) agreed. When asked whether they feel their students have math anxiety, 53 percent of teachers agreed. This is in contrast to the responses given by students to statement six on the Student Survey (Figure 1). A majority of students felt they were not nervous and felt confident in their ability to do the work. The surveyed teachers overwhelmingly agree that math vocabulary affects student achievement and is important to teach.

Teacher Questionnaire

A questionnaire was distributed to the fourth and fifth grade teachers at the targeted sites. (Appendix D) Fifteen teachers were asked to list the strengths and weaknesses of their mathematics programs and comment on the level of mathematics vocabulary of students at the targeted sites. They were also asked to indicate which topics had been covered in the previous year.

Teachers were asked to list three strengths and weaknesses of their mathematics program. Twenty-two different responses were listed as strengths of the programs. Eight teachers listed review of skills as a strength. A good balance of skill levels was listed by six teachers. Four teachers believe the programs are teacher-friendly and provide several teaching options. Other responses include mental math strategies, thinking skills, problem solving, real-world problems, and easy to assess. Twenty-three different responses were listed as weaknesses of math programs. Seven teachers stated the program is boring and does not provide enough supplemental materials or manipulatives. Six teachers stated there was too much reading and not enough focus on computation. At Site B, two different mathematics programs are used. Depending on the math program used, teachers' responses varied. Four teachers listed this lack of coordination between grade levels as a weakness in the math program. Three teachers felt there is not enough emphasis on vocabulary. Overall, most teachers feel that their current math programs adequately focus on problem solving, but feel that in general their programs are lacking extension activities.

When asked whether they feel students have a strong math vocabulary, teachers overwhelmingly responded no. Students know the words but do not know when to use them, or they know the operation but do not know the vocabulary term that is used to represent that operation. Teachers complained there is not enough reinforcement of correct mathematical terms, and students often get them confused or have difficulty remembering them. One teacher felt that the level of students' mathematical vocabulary depended on the previous year's teacher.

Most teachers feel that their current math programs adequately introduce mathematics vocabulary but do not emphasize and reinforce it. There are too few lessons focusing on vocabulary, and these are too brief.

In response to the last open-ended question, fourteen teachers believe a lack of understanding of math vocabulary affects test scores. Often students don't understand what is being asked of them in a word problem. If they do not understand the word problem, they do not know what operations to perform to solve it. According to one teacher, students need to be aware of a variety of terms for proper interpretation of a word problem. They need to know how to attack problems and read the vocabulary.

The last question on the Teacher Questionnaire asked teachers to circle the topics they covered in math class last year. A total of 46 topics were listed in 22 different categories. Categories ranged from basic computation to graphing and geometry. The data are presented in Table 2.

Table 2

Teacher Questionnaire – Mathematics Topics Covered

TOPIC COVERED	# OF TEACHERS	% OF TEACHERS	TOPIC COVERED	# OF TEACHERS	% OF TEACHERS
Addition-Whole Num.	14	100	Bar Graphs	11	79
Addition-Decimals	13	93	Line Graphs	12	86
Addition-Fractions	8	57	Circle Graphs	10	71
Subtraction-Whole Num.	14	100	Decimal Place Value	14	100
Subtraction-Decimals	12	86	Triangle Identification	14	100
Subtraction-Fractions	7	50	Triangle Area Formula	8	57
Multiplication-Whole Num.	14	100	Triangle Perimeter	13	93
Multiplication-2 Digit Factors	14	100	Circle Parts	10	71
Multiplication-3 Digit Factors	10	71	Circle Area Formula	9	64
Multiplication-Decimals	10	71	Circle Circumference	10	71
Multiplication-Fractions	5	36	Quadrilateral Identification	13	93
Division-Whole Num.	14	100	Quadrilateral Area Formula	9	64
Division-1 Digit Divisors	14	100	Quadrilateral Perimeter	12	86
Division-2 Digit Divisors	11	79	Other Polygon Identification	13	93
Division-Decimals	8	57	Other Polygon Area Formula	5	36
Division-Fractions	5	36	Other Polygon Perimeter	11	79
Equivalent Fractions	11	79	Prism Identification	11	79
Reducing Fractions	9	64	Prism Surface Area	5	36
Probability	8	57	Prism Volume	4	29
Measurement – Standard	13	93	Pyramid Identification	9	64
Measurement – Metric	11	79	Pyramid Surface Area	2	14
Ratio	7	50	Pyramid Volume	2	14
Percents	11	79	Other Polyhedrons	1	7

In analyzing the responses presented in Table 2, the data suggests that teachers inconsistently covered the range of topics. Out of the 46 possible topics, only eight were covered by 100 percent of the teachers surveyed. These topics include basic computation. Fourteen topics were covered by more than 75 percent of the teachers surveyed, and eight topics were covered by less than 50 percent of the teachers surveyed. These eight topics included more advanced geometry and fractions. It is evident from this data that students entering the targeted fifth grade classes have a varied experience with mathematics. The topics covered by teachers in fourth and fifth grades are not consistent, causing students to enter the next grade level with diverse mathematical backgrounds.

In comparing this data to the data presented in Table 1, students and teachers are in agreement on most topics. The students' responses are generally lower than the responses given by the teachers. This is to be expected, since students usually forget some of what was taught the previous year.

Math Vocabulary Checklists

Two separate vocabulary checklists were developed and administered to the targeted fifth grade students using the Grade 5 Word List from the 2000 Illinois Standards Achievement Test (ISAT) Math Sample Test. These checklists can be found in Appendices E & F. The words were presented in alphabetical order to eliminate any word associations. Forty-three students were asked to check the box corresponding to their level of understanding for each vocabulary word: high, average, and low. They were also asked to provide a definition or example for each of the 69 words presented.

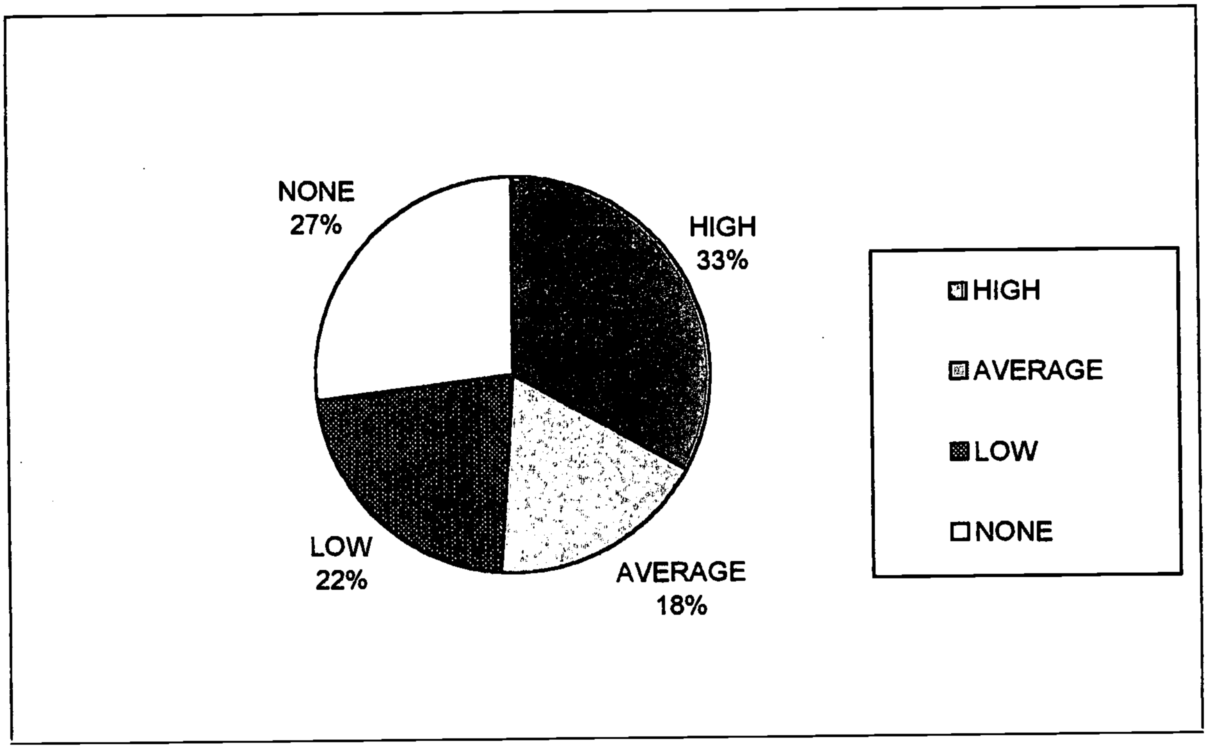

Figure 3. Math vocabulary checklist 1.

Math Vocabulary Checklist 1 contained 35 words that included terms dealing with general math concepts such as: addends, area, dividend, equation, fraction, mean, parallel, percent, product, quotient, ratio, sum, and volume. Half of the students had low or no understanding of these general math terms. The words least understood by students include: chord, congruent, mean, perpendicular, prime number, radius, similar, symmetry, vertex, and volume. These least-understood terms correlate to the topics students marked on the Student Questionnaire as not having been covered the previous year. Students were most familiar with terms: area, equation, parallel, product, and sum. This checklist will be re-administered after the interventions have been implemented. These data will be presented in Chapter Four.

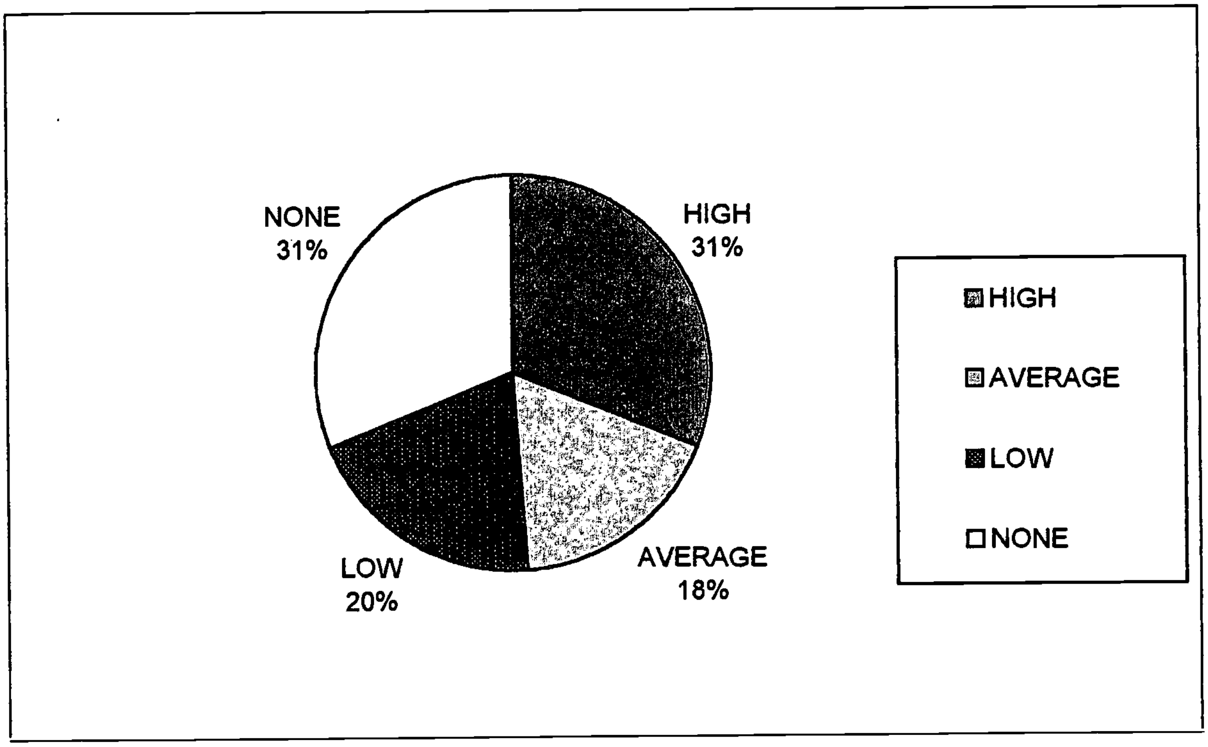

Figure 4. Math vocabulary checklist 2.

Math Vocabulary Checklist 2 contained 34 words that included terms dealing with general geometric concepts such as: two-dimensional, three-dimensional, cone, equilateral triangle, octagon, quadrilateral, rectangle, rhombus, slide, sphere, and prism. More than half of the students had low or no understanding of these geometric terms. The words least understood by students include: equilateral triangle, flip, quadrilateral, prism, pyramid, polygon, rotation, slide, and turn. These least-understood terms correlate to the topics students marked on the Student Questionnaire as not having been covered the previous year. Students were most familiar with the terms: cube, cylinder, hexagon, rectangle, sphere, square, trapezoid, and triangle. As with Math Vocabulary Checklist 1, this checklist will also be administered as a posttest after the interventions. These data will be presented in Chapter Four.

After comparing the data presented in Figures 3 and 4, it is evident that the students in the targeted fifth grade classrooms have poor mathematical vocabularies.

Probable Causes

Knowledge of mathematics and the ability to apply that knowledge to solve problems is essential, not only while in school, but later in life. This mathematical understanding will enable the students of today to participate fully as workers and citizens of tomorrow. Unfortunately, many students do not have the mathematical knowledge necessary to be proficient problem solvers, especially in the area of vocabulary.

There are several underlying causes that contribute to students' poor mathematical vocabulary. The following are causes for students having difficulty comprehending mathematical terminology: students have different mathematical backgrounds, students have math anxiety and/or low self-esteem in math, the majority of math series focuses on computational facts, expectations of students have shifted due to a change in ISAT/NCTM standards, and students have poor reading comprehension.

Different Mathematical Backgrounds

In the targeted sites, it has been noted that students arrive in the classrooms with a varying degree of understanding of mathematical vocabulary. No two students come to the classroom with the same mathematical experiences. Students exhibit varied needs, achievements, abilities, interests, and talents in math (NCTM, 2000). Some of the contributing factors of this problem include: a lack of emphasis on math vocabulary in textbooks, inconsistent use of vocabulary in previous grades, not finishing topics covered in previous grades, inconsistent teacher preparation/attitudes/previous experiences, ESL/foreign students, and different math series used in previous grades.

Current research shows that mathematics needs to be a universal language. In 1995, Lola May concluded, "A common vocabulary is essential for any type of successful communication in mathematics" (p. 24). This is not always a realistic goal. Teachers often do not introduce appropriate mathematical terminology in the primary grades. Some students may know the difference between sum, difference, product, and quotient, while others may only know them as the answer.

Teachers have little or no control over the entry-level math abilities of their students. Teachers are left to assume that incoming students have achieved the necessary skills for success in the previous grades (Nolting & Savage, 1991). They have no guarantees that all students have these skills.

Math Anxiety and Low Self-Esteem

In the targeted fifth-grade classrooms, it has been noted through observation that students often exhibit signs of nervousness and apprehension when it comes to learning math. This is viewed through the following: feelings of tension and anxiety when working with numbers and trying to solve math problems, a state of panic, helplessness, and mental confusion that occurs when having to solve mathematical problems, and a negative attitude toward mathematics in general. This "math anxiety" can cause academically capable students to struggle with math. Math anxiety can even develop into the more serious math avoidance and math phobia (Tobias, 1978).

The literature suggests that many people think of mathematics as a punishment or something that induces stress (Zaslavsky, 1994). It is no wonder then that so many students enter the classroom with a lack of confidence in mathematics ability. It is also noted that family and peer attitudes may affect an individual's level of confidence (Stuart, 2000). For example, a parent that does not show interest or enthusiasm for math may invoke a negative attitude toward math in their child, possibly even causing the child to have math anxiety.

Susan Ohanian (1989) proposes that children have a natural curiosity about math. From the moment they learn how to walk and talk they discover patterns and numbers in their world. "Yet, for many, math too soon becomes a forbidding system of rigid rules governed by speed, accuracy, and memory" (Ohanian, 1989, p. 32). This can cause mathematics to be viewed as threatening and something to be avoided.

Focus on Computational Facts

It has been noted in the targeted classrooms that the traditional instructional materials used to teach math focus heavily on computational skills versus vocabulary. Typical mathematics instruction consists of paper and pencil drills of basic computation and rote memorization of facts and algorithms. In a study conducted in 1978, Welch observed mathematics lessons and found a similar pattern:

> First, answers were given for the previous day's assignment. A brief explanation, sometimes none at all, was given of the new material, and problems were assigned for the next day. The remainder of the class was devoted to students working independently on the homework whole the teacher moved about the room answering questions. The most noticeable thing about the math classes [that were observed] was the repetition of this routine. (p. 6)

The same thing is still occurring in many of today's mathematics classrooms. Teachers show students exactly how to solve a particular type of problem, and students sit quietly at their desks and practice (Kliman & Kleiman, 1992). Few efforts are made to make connections from the skills presented and the application of those skills. According to Marian Small (1990), "This emphasis [on computation] was useful when the primary goal of mathematics education at the elementary level was to create proficient calculators. However, it is no longer necessary to create expert human calculators; society now depends on electronic ones" (p. 26). The focus should be on helping students develop conceptual ideas, not on computational procedures.

Yet, the majority of math textbooks in elementary classrooms still relies on drill and practice with an occasional isolated definition of a new math term. "Without an understanding of the vocabulary that is used in mathematics instruction, textbooks, and word problems, students are handicapped in their efforts to learn mathematics" (Miller, 1993, p. 312). The problem is illustrated when a student, who can perform the task of two plus three, cannot do the same task when asked to find the sum of two and three. Students do not understand that plus, find the sum, and add all refer to the same operation.

Students must understand the language of math in order to fully comprehend concepts being learned. Carolyn Moore argues (1995), "Not only do our students have to be able to solve the problem, they must be able to explain how they arrived at the answer and why the answer is correct" (p.50). This is not possible for students who are accustomed to the traditional drill and practice of computational facts. They are unable to explain to others their mathematical thinking because they have been taught to rely on the rote memorization of facts rather than making their own connections. Students who memorize facts or procedures without understanding are often not sure when or how to use what they know (Bransford, Brown, & Cocking, 1999). They have memorized the operation but not the concepts that accompany it.

The literature suggests there is a lack of communication in the teaching of mathematics. Instructional methods such as discussion and journal writing are not traditionally implemented in the mathematics classroom. A study conducted in 1988 found that "mathematics instruction continues to be dominated by teacher explanations, chalkboard presentations, and reliance on textbooks and workbooks" (Hatfield, Edwards, & Bitter, 1999, p. 12). Marian Small (1990) has noted that students rarely speak more than a few words during a math class. She goes on to state:

> Educators and parents are all aware of the importance of regularly talking to children to enhance their language development in particular and their general intellectual growth in general. These experiences give children opportunities to experiment with language, to interact with others through a language medium, and to participate meaningfully in the world of ideas. (p. 26)

So why are there so few attempts made in the mathematics classroom to offer these verbal opportunities to our students?

Expectation Shift Due to ISAT and NCTM Standards

In the targeted sites, it has been noted that the expectations for our students have shifted in the last few years due to changes made in the state and national standards. The Illinois State Standards, adopted in 1997, emphasize mathematics communication, and in 1999, Illinois restructured its achievement testing, the Illinois Standards Achievement Test (ISAT), to include mathematics in fifth grade.

In addition to the change in grade levels being tested, a new testing format was designed. This new assessment shifted the focus from computational facts to vocabulary and logical reasoning. Students are now required to have a vast knowledge of mathematical terminology as well as have the ability to effectively communicate their knowledge in writing. In the 1999 ISAT Sample Math Materials, the Illinois State Board of Education states:

> Mathematics is a language we use to identify, describe and investigate the patterns and challenges of everyday living. It helps us understand the events that have occurred and to predict and prepare for events to come so that we can more fully understand our world

> and more successfully live in it. Mathematics is much more than a collection of concepts and skills; it is a way of approaching new challenges through investigating, reasoning, visualizing and problem solving with the goal of communicating the relationships observed and problems solved to others. (p. 2)

The ISAT Sample Test continues to add that students must not only be able to describe how he or she solved a problem, but must also describe why he or she chose those steps, using the appropriate mathematical terminology (1999). These open-ended questions are given a score for mathematical knowledge (correctly solving the problem), strategic knowledge (selecting and implementing an appropriate problem-solving strategy), and written explanation (the solution process translated into words including justification for each step).

The changes made to the ISAT assessments are a direct result of the standards set forth by the National Council of Teachers of Mathematics (NCTM) which stress the importance of oral and written communication in mathematics instruction. One of the ten standards revised in 2000 specifically focuses on communication, stating that all students should be able to: organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to their peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; and use the language of mathematics to express mathematical ideas precisely (NCTM, 2000). Without a strong understanding of mathematical vocabulary, students are incapable of meeting these new state and national standards.

<u>Poor Reading Comprehension</u>

In the targeted classrooms, it has been noted that a relationship exists between students' poor reading comprehension and a lack of understanding of mathematical terminology. This is especially true when observing students' errors in mathematical word problems. It is assumed that students are reading the problems correctly and comprehending what is being asked of them. Many times this is not the case. Students often search the problems for numbers rather than attempting to comprehend what is truly being asked in the problem. The researchers have observed that the targeted students do not understand how to make the connections between the words and the numbers.

Students' lack of understanding when attempting to solve a mathematical problem is often a direct result of the inability to read the problem effectively. A student needs to be proficient in reading and skilled at mathematics to solve word problems (Matz & Leier, 1992). Yet, reading strategies are rarely implemented in the teaching of mathematics as an aid in comprehension.

Upon reviewing the literature, it is noted that the language of mathematics is more difficult to read than any other area. It is therefore more crucial to emphasize vocabulary instruction in this content area. Eula Ewing Monroe and Robert Panchyshyn (1995) state, "The importance of rich and meaningful vocabulary knowledge when developing concepts is well documented and widely accepted by classroom teachers" (p. 80). However, this rich vocabulary is often neglected in the mathematics classroom. Students who do not have access to the meaning of words "representative of the concepts and content of what they read causes difficulty in children's comprehension of texts, limits their ability to make a connection with their existing background knowledge, and inhibits their capacity to make coherent inferences" (Rupley, Logan, & Nichols, 1998, p. 336).

CHAPTER 3

THE SOLUTION STRATEGY

Literature Review

All students need to have a strong understanding of mathematical vocabulary in order to be successful math students. Mathematical vocabulary is extremely important to teach since it can greatly affect students' achievement. There are several factors that contribute to the ineffectiveness of the teaching of math terms. Most notably, vocabulary instruction is not a focus in the teaching of math, nor is it stressed in the overwhelming majority of mathematics textbooks. The comprehension of mathematical vocabulary is generally assumed and therefore not a priority.

The topics for discussion that have been found to be solutions for students' poor mathematical vocabulary include: un-learning incorrect vocabulary, teaching math study skills, allowing students to have the same experiences, using math vocabulary within a meaningful context in instruction, immersing students in the language of math, making writing an integral part of math class, increasing the focus on the standards, employing children's literature to help students understand math terms, and utilizing reading strategies to teach vocabulary.

Un-learning Incorrect Vocabulary

In order to fully comprehend the language of math, a common vocabulary must be learned. If the vocabulary has not been taught as a universal language, students will most likely struggle with their comprehension. Lola May (1995) argues that in many cases students need to get rid of bad habits that may have been learned in mathematics, specifically un-learning incorrect vocabulary. For example, a student that reads the problem $11 - 5 = 6$ as "eleven take away five is six", has not learned correct terminology. Using the term, "take away", should only refer to physically taking an object away. Students need to recognize that the minus symbol represents subtraction. Some other examples of mathematical vocabulary students should be taught are: addend, sum, product, factor, dividend, divisor, quotient, and difference.

A universal mathematical language is essential in other areas of mathematics as well. To effectively communicate properties of geometry, for example, a common language is required (May, 1995). Students may need to re-learn that a corner is also called a right angle. This un-learning of vocabulary is vital as students move through the grades. "Most children are interested in learning new words, and there is little reason ever to use an incorrect term" (Riedesel, 1990, p. 34).

Teaching Math Study Skills

Skills like test taking, listening, note taking, time management and memory are important to the understanding of mathematics. However, most students do not know how to study math because they have not been taught how to study math. Paul Nolting and William A. Savage (1991) contend that many math teachers were never formally taught math study skills themselves. In 1991, Nolting and Savage presented the following five ideas in their book, Successful Math Study Skills, to help teachers teach math study skills to their students:

1. Learning to think and learning to organize thoughts are a major part of math. Common ideas run through all math classes, and these ideas need to be pointed out to students to make them aware of connections between new and previously learned material. Skills learned in previous classes are needed to master concepts and ideas

in following courses. Time should be allowed for daily practice. Like any sport, math must be practiced to learn new skills and increase proficiency with previously learned skills.

2. Teachers should encourage students to save pages from the back of their notebooks to record new terms and their definitions. Students should be given the formal definition and be able to give a definition in their own words. When this is achieved, students are better able to fully understand the term.
3. Encourage students to work on assignments together. Studying with a partner leads to increased understanding for both students. The true test of knowledge and understanding occurs when a student can explain a concept or term to another student.
4. Help student to use their class time wisely. Most elementary students are unable to gauge how long an assignment will take them. Teach students to look over the entire assignment first to check for any areas of questions that can be answered at school rather than when the student is finishing the assignment at home.
5. Teach students how to take notes. Note taking in the math class may be quite different than note taking in social studies or science. Encourage students to copy each and every step to sample problems with explanations.

It is important to remember that mathematics is a skill subject, similar in many ways to playing an instrument or learning a foreign language. Passive participation will not suffice. Learning will not take place unless the subject is practiced.

Allowing Students the Same Experiences

Children need to be given opportunities to experiment with language, to interact with others using language, and to be able to communicate meaningfully (Small, 1990). These same experiences need to be made available to students in the mathematics class as well. Attempts must be made to provide opportunities for students to interact with each other and have conversations about mathematics. In addition to having this interaction with one's peers, students must also be allowed to "speak the math language" with their teachers. Marian Small (1990) contends that students rarely speak mathematics with their teachers other than the occasional answering of a direct question or asking for a re-explanation. By allowing all students these same enriching language experiences in math, it helps to involve students more fully in the mathematical processes, thereby increasing comprehension as well as enjoyment for mathematics.

New students entering the classroom oftentimes can cause a problem. The student has most likely been taught from a different mathematics series and therefore may have a different knowledge base with which to work. All teachers need to be aware of this, not only at the start of a new year, but as any new student arrives. In order to provide students the same mathematical experiences, teachers need to first determine the mathematical foundation of the students. By distributing a placement test or vocabulary checklist to all students the teacher can become more familiar with the prior knowledge of each student.

Using Math Vocabulary in a Meaningful Context

According to Reys, Suydam, and Lindquist (1995), mathematical learning can and must have meaning. In order to accomplish this, an emphasis on understanding rather than memorization must be done. The mathematics vocabulary that is to be learned must make sense to the learner. A problem that arises when attempting to provide a meaningful context is that many terms used in mathematics have different meanings in everyday language. For example, the terms difference, product, similar, face, volume, and table all have multiple meanings

(Anghileri, 1995). Vocabulary must be taught in context. To truly comprehend a word, a student needs to understand how it affects the meaning of a passage and how it helps to convey a thought. Anghileri continues, "the language of spoken (and most written) mathematics is always blended into a natural language (English), and the distinction between the two languages is often blurred" (1995, p. 58). It is because of this fact that teachers of mathematics need to carefully consider how mathematical vocabulary is introduced, reinforced, and mastered.

In many of the current mathematical textbooks, the vocabulary is introduced before the concept is considered, which can create difficulty. In many cases, allowing the students opportunities to experiment with the concept and develop their own meanings before teaching the actual terminology can greatly increase comprehension. When students are able to make their own connections in this way, they are less likely to be frightened off by an isolated, early introduction of a term. C. Alan Riedesel (1990) suggests that learning the word after the idea has been developed and when there is a need to discuss "what we know" gives students a feeling of accomplishment. Children need these opportunities to talk about, listen to, and read and write about mathematics in a meaningful way.

Immersing Students in the Language of Math

In order for students to feel comfortable with any concept or idea, they must constantly be reminded of it. In mathematics instruction "teachers need to be aware that math anxiety is a real affliction that affects many of our students" (Stuart, 2000, p. 9). In an effort to help reduce or even eliminate math anxiety, students need to become actively involved in the processes of mathematics. Teachers need to incorporate language into the teaching of mathematics in order to immerse students in mathematical processes (Small, 1990). Small makes the suggestion to ban pencils and workbooks in an effort to give teachers and students the opportunity to verbalize their mathematical ideas. The no-pencil approach forces the teacher to do a better job of explaining and the students to pay closer attention. This leads to increased student comprehension of mathematical terms, as well as easing students' overall apprehension toward mathematics.

Another strategy for immersing students in mathematical language is through cooperative learning. Carolyn Moore (1995) believes that children learn best from other children. Information and terminology that is shared among students is usually done in a non-threatening way. It provides opportunities for students to express themselves in ways they may not feel comfortable doing with their teachers. In a study conducted by Vanessa B. Stuart (2000), it was found that most students appreciated the opportunity to work in cooperative groups. In some cases the students felt that their peers could explain things better than their teacher. Cooperative learning is a meaningful setting for discussion of mathematical concepts.

Using more discussion in the instruction of mathematical vocabulary is another strategy to immerse students in the language of mathematics. For many students, mathematics is a "forbidding system of rigid rules governed by speed, accuracy, and memory" (Ohanian, 1989, p. 32). As a result, mathematics can become boring for some students or threatening for others. By encouraging discussions in the mathematics classroom, teachers can foster a more positive attitude. Susan Ohanian (1989) believes that even in math class, open-ended discussions can leave room for emotion, intuition, creativity, and humor. Discussion also gives teachers the opportunity to model the use of appropriate mathematical vocabulary when interacting with students. For example, when a teachers asks, "How did you find the answer?" they should really be saying, "How did you find the sum (product, difference, perimeter, etc.)?" (Monroe & Panchyshyn, 1995).

Making Writing an Integral Part of Math Class

Educators have long known the value of using writing across the curriculum. However, "writing has never been seen as a natural part of the mathematics curriculum the way it has been for subjects like science and social studies, in which students have traditionally written at least answers to textbook questions" (Wilde, 1991, p. 38). In mathematics, as in other subjects, writing is a way for students to think about what they do know, ask questions about what they don't know, explore a topic on their own, and express any anxieties they may have (Ohanian, 1989). Incorporating written communication into the mathematics curriculum is necessary for students to be able to reflect and process what they learn, thereby increasing comprehension.

Both the Illinois Standards Achievement Test (ISAT) and the National Council of Teachers of Mathematics (NCTM) call for an increase in using writing in the construction of mathematical understanding. Lewis, Long, and Mackay (1993) state:

> The NCTM's curriculum standards document supports writing as a legitimate means of learning mathematics and proposes that teachers engage students in composing written answers to problems, writing letters to friends explaining what they are learning in mathematics, or keeping a journal to record their reflections about mathematics. (pp. 471-472)

As a result of this proposal by the NCTM, teachers are striving to find ways to implement writing into their daily math lessons. Donald J. Haggerty and Susan E. Wolf (1991) compiled a list of writing ideas that could be used. They incorporate three basic writing types: narrative, descriptive, and expository. They suggest the following ideas:

Narrative Writing

1. writing biographical sketches

2. writing word problems

3. using mathematics in the work world

4. writing stories

Descriptive Writing

1. writing how-to paragraphs

2. writing a business letter

3. defining mathematical vocabulary

4. creating "what am I" descriptions

5. writing historical stories

6. summarizing

7. using sports statistics

8. writing directions using measurements

9. using geometric figures

10. using mathematics in everyday life

Expository Writing

1. interpreting graphs

2. correcting a problem

3. persuading others using statistics

4. getting feedback from students.

This list is not inclusive of every way writing may be included in the mathematics classroom, but it does make teachers begin to question how they may have their students write about and with mathematics.

Coreen L. Mett (1989) suggests having students write daily in a mathematics journal to help them explore what they do and do not understand and to help them apply new concepts to their own experience. She contends that journaling should have three main parts: a summary of new material learned in class; a discussion of individual work outside of class; and an analysis of connections, difficulties, and open questions.

L. Diane Miller (1992) adds that writing is an excellent way to begin the math class as well. Prompts can be presented at the beginning of math class to constructively engage students in a math related activity relevant to the day's topic for instruction. Students begin formulating their own ideas and have begun to process the topic. The prompts offer students a non-threatening opportunity to write about the subject matter. Because writing is an active process that promotes students' procedural and conceptual understanding of mathematics, students often find out what they think when they write. Writing gives students an opportunity to reflect on, and clarify their thinking about, mathematical ideas and relationships.

Haggerty and Wolf (1991) offer these guidelines for student writing:

1. Students should write everyday. Teachers should check student notebooks and journals.
2. Teachers should write with students and share their work. As a modeling technique, teachers should read aloud or provide copies of their own written work.
3. Students should be encouraged to write in complete sentences. However, grammar, spelling, and syntax should not be the primary focus. Logical thinking as evident in organized, complete thoughts is the focus.

4. Teachers should make students feel good about their writing. Student writing should be posted in the classroom. Praise students for their efforts and discoveries.

Having students write during math class enhances cognitive development. It requires that students reflect on their reasoning. By writing, they explore, clarify, confirm, and extend their thinking and understanding (Burns, 1988).

Increasing the Focus on the Standards

In 1999, Mary M. Hatfield, Nancy Tanner Edwards, and Gary G. Bitter asked, "How do we (as teachers) prepare elementary-school children and middle-schoolers for mathematical experiences we have never had ourselves?" (p. 4). Teachers need to be aware of the "big picture" when deciding what to teach and how to teach it. Everyone needs to understand mathematics. All students should have the opportunity and the support necessary to learn significant mathematics with depth and understanding, and the National Council of Teachers of Mathematics (NCTM) has developed *The Principles and Standards For School Mathematics* to assist educators in providing these opportunities. *The Standards* cover the who, what, where, why, how, and how much in mathematics instruction.

The main goal of these ten standards deals with the "big picture" of mathematics. The first five Standards describe mathematical content goals in the areas of number and operations, algebra, geometry, measurement, and data analysis and probability. The last five Standards address the processes of problem solving, reasoning and proof, connections, communications, and representation. The document is divided into grade-band chapters, where the Standards are discussed and a set of grade-level expectations is identified. *The Principles and Standards For School Mathematics* offers teachers and curriculum developers a way to focus mathematics curricula. According to NCTM (2000), *The Principles and Standards For School Mathematics* is intended to:

1. set forth a comprehensive and coherent set of goals for mathematics for all students from pre-kindergarten through grade 12 that will orient curricular, teaching, and assessment efforts during the next decades;
2. serve as a resource for teachers, education leaders, and policymakers to use in examining and improving the quality of mathematics instructional programs;
3. guide the development of curriculum framework, assessments, and instructional materials;
4. stimulate ideas and ongoing conversations at the national, state, and local levels about how best to help students gain a deep understanding of important mathematics (p. 6).

Standards can play a central role in the process of improvement. Aligning curriculum to state and national standards will ensure all students have access to essential knowledge.

In 1997, the Illinois State Board of Education (ISBE) released the *Illinois Learning Standards*. The mathematics goals were influenced by the NCTM, local projects, results of assessment findings, and the work and experiences of Illinois school districts and teachers. The mathematics standards propose that mathematics is a language that we use to identify, describe, and investigate the patterns and challenges of everyday living. It helps us to understand the events that have occurred and to predict and prepare for events to come so that we can more fully understand our world and more successfully live in it. "Mathematics is much more than a collection of concepts and skills; it is a way of approaching new challenges through investigating, reasoning, visualizing, and problem solving with the goal of communicating the relationships observed and problems solved to others" (ISBE, 1997, p.16).

The ISBE has identified five Applications of Learning that cross academic disciplines and reinforce the important learning of the disciplines.

1. Solving Problems: The solving of problems is at the heart of doing mathematics. When people are called on to apply their knowledge of numbers, symbols, operations, measurement, algebraic approaches, geometric concepts and relationships, and data analysis, mathematics' power emerges. Students must have experiences with a wide variety of problem solving methods and opportunities for solving a wide range of problems. The ability to link the problem-solving methods learned in mathematics with a knowledge of objects and concepts from other academic areas is a fundamental life survival skill.
2. Communicating: Everyone must be able to read and write technical material to be competitive in the modern workplace. Mathematics provides students with the opportunities to grow in the ability to read, write, and talk about situations involving numbers, variables, equations, figures, and graphs. The ability to shift between verbal, graphical, numerical, and symbolic modes of representing a problem helps students formulate, understand, solve, and communicate technical information. Students must have opportunities in mathematics classes to confront problems requiring them to translate between the different representations, both within mathematics and between mathematics and other subject areas; to communicate findings both orally and in writing; and to develop displays illustrating the relationships they have observed.
3. Using Technology: Technology provides a means to carry out operations with speed and accuracy. The technology of paper and pencil is appropriate in many mathematical

situations. In many other situations, calculators or computers are required to find answers or create images. Students must be able to use the technology to represent information, form conjectures, solve problems, and communicate results.

4. Working on Teams: The use of mathematics outside the classroom requires sharing expertise as well as applying individual knowledge and skills. Working cooperatively in groups allows students to share ideas, to develop and coordinate group approaches to problems, and to share and learn from each other. Students must have opportunities to develop these processes and skills provided by team problem solving to be prepared to function as members of society and productive participants in the workplace.
5. Making Connections: Mathematics is used extensively in business; the life, natural, and physical sciences; the social sciences; and in the fine arts. Mathematics provides the necessary tools and ways of thinking to unite the concepts, relationships, and procedures common to these areas. Mathematics provides a language for expressing ideas across disciplines, while, at the same time, providing connections linking number and operations, measurement, geometry, data, and algebra within mathematics itself (1997).

The ability to use these applied learning skills will greatly influence students' successes in school, in the workplace, and in the community.

The ISBE has identified five state mathematics goals involving numbers and operations, measurement and estimation, algebra and data interpretation, geometry, and statistics and probability. Each of these state goals includes a communication aspect, both written and oral. Aligning curriculum to the *Illinois Learning Standards* will ensure that all students in Illinois have a solid foundation for success in the workplace, a basis for continued learning about mathematics, and a foundation for confronting problem situations throughout their lives.

Using Children's Literature

Children's literature is commonly used to enhance language arts, social studies, and even science lessons. However, it is rarely used in the mathematics classroom (Gailey, 1993). One strategy to increase students' mathematical knowledge and understanding is to make connections between mathematics and children's literature. Gailey continues:

> Of the more than two thousand children's trade books published every year, a number can be used to introduce, reinforce, or develop mathematics concepts. Not only librarians should familiarize students with these trade books; mathematics teachers also should include these books in their lessons (p. 258).

By using children's literature, learning of mathematics is enhanced. Mathematics and language skills can develop together as students listen, read, write, and talk about mathematical ideas.

David J. Whitin (1992) proposes the following ideas regarding the incorporation of children's literature into the mathematics curriculum:

1. Children's literature can help learners value mathematics.
2. Children's literature helps learners build their confidence in their own mathematical abilities.
3. Children's literature encourages learners to be mathematical problem solvers.
4. Children's literature provides a meaningful context for children to communicate mathematically.
5. Children's literature supports learners in reasoning mathematically (pp.24 – 28).

Whitin concludes by stating, "Children's books have the potential for helping children better understand mathematical ideas and their application to real-world situations" (p.28). He also recommends that teachers encourage their students' to make personal connections to the stories in order to further increase their comprehension.

By incorporating children's literature in the mathematics curriculum, teachers are encouraging students to use mathematical language, skills, and concepts in other curriculum areas (Jennings, Jennings, Richey, & Dixon-Krauss, 1992). Making these connections are essential for the increased comprehension of mathematical vocabulary.

Lewis, Long, and Mackay (1993) suggest that mathematics teachers who share children's literature in their lessons need to give time and opportunity for their students to respond to the ideas in the story. Teachers can also elicit mathematical thinking through questioning. These, as well as other reading strategies, are discussed in the next section.

Using Reading Strategies

Karl A. Matz and Cynthia Leier (1992) believe a student must be both proficient in reading and skilled at mathematics to solve a word problem. Most elementary mathematics textbooks use a general vocabulary, although these words are not likely to be taught in reading class (Monroe & Panchyshyn 1995/1996). However, the methodology and activities teachers have developed for teaching vocabulary in other areas can be just as appropriate for the mathematics lesson. Monroe and Panchyshyn (1995/1996) present the following suggestions for implementing reading and vocabulary instruction in mathematics:

1. Use concrete experiences with manipulatives to develop a concept. Guide oral language development as students work with the manipulatives.
2. Examine the textbook lesson carefully ahead of time to identify terms that will be new for the students. Select a few key terms that can serve as organizers for the concepts to be taught. Teachers should be prepared to provide help concerning any symbols and general vocabulary that may create reading problems.

3. Teach and extend vocabulary in relation to students' real world experiences.
4. Students who do not have enough relevant prior experiences with concepts need pre-reading activities, such as brainstorming and semantic mapping, to encourage discussion. Ask the class to brainstorm all known definitions to a term to be covered in the lesson. Semantic mapping is also useful when introducing a new topic, as it "helps to activate and expand prior knowledge; it also helps students learn new words" (Johnson & Johnson, 1986, p. 625).
5. Take time to teach the little words in mathematics class. Even words such as *a* and *the* can be confusing.
6. Teach mathematics symbols only after students have the necessary experiential background and language development to understand them.
7. Introduce and develop pertinent vocabulary in each mathematics lesson, and then review the words frequently. Provide six exposures to a new word during the initial lesson and at least 30 additional exposures during the ensuing month. New vocabulary should be repeated often in meaningful settings before students will retain and actually use it to construct mathematical concepts.
8. Model the use of appropriate mathematics vocabulary when interacting with students.
9. Give students many opportunities to talk about new mathematical concepts. Discussion will be greatly facilitated through cooperative learning groups and peer tutoring.
10. Use writing assignments to develop mathematics vocabulary. Students will enjoy drawing pictures and writing definitions to create their own math dictionaries. They could also keep journals of concepts.

11. Share selections from children's literature. Some books are specifically designed to teach mathematics concepts.
12. Teach students to read math textbooks slowly and carefully, stressing that every word and symbol is important to their understanding. Teach them to use text guides, such as boldface print and definitions. Students need to use text effectively and to learn concepts independently.
13. As students learn new dictionary skills, encourage them to learn new math vocabulary on their own by consulting the glossaries in their mathematics textbooks as well as math dictionaries. Students should keep fine-tuning until they find the correct definition for the word, especially when using a regular dictionary (pp. 80 –83).

Many of these ideas are used in the science, social studies, or reading classrooms, but rarely are they applied to the mathematics classrooms.

A word web is another way to involve reading strategies in the teaching of mathematics vocabulary. "A word web is a thought-organization and clarification strategy" (McGehe, 1991, p.36). It is already used by many teachers in language arts, science, and social studies, but rarely in mathematics classes. After writing a key word or phrase in the middle of the board or paper, students respond to the word with any knowledge or feelings they have about the word. As the students brainstorm ideas, the teacher writes the responses around the word, organizing the word into categories. However, the categories are not revealed to the students. Once students notice the pattern of the categories, they begin to suggest where the next idea should go. Once all ideas have been recorded, students are asked to title the categories (McGehe, 1991). This web can be modified from a whole-class discussion into an individual assignment. It can be used as a pre-activity to see what students already know or as an assessment tool to see what students have learned.

Examining word origins is another way to teach mathematics vocabulary. Once teachers are familiar with the roots of mathematical terms, these etymologies can be shared with students as new vocabulary is introduced. The word roots can be used as bridges to meaning (Rubenstein, 2000).

Mathematical terms are often linked with common English words. These links promote vocabulary development, as well as mathematical fluency. An example is the fact that students often confuse the terms *diameter* and *radius*. Radius comes from the same root as *ray*. Just as a ray of sunshine goes out from a point at the center of the sun, so too does a radius of a circle start at the center and radiate out. Once students understand these roots, they begin to see the connections between words. *The Words of Mathematics* (1994) by Steven Schwartzman provides the etymologies of hundreds of mathematical terms, along with examples of related roots in common language.

Teachers can begin the concept of word origins with their classes by sharing an etymology when a new concept is first introduced. Encourage students to brainstorm any words that appear to be related (cognates) and check dictionaries to check definitions. Mathematical terms often mean precisely what they say. Once the roots are recognized and understood, their meanings are clear. Word origins appear across all disciplines, and teachers who are aware of terms students are learning in other classes can use etymologies to support student learning in all areas (Rubenstein, 2000).

Topics discussed as possible solutions for students' poor comprehension of mathematical vocabulary are: un-learning incorrect vocabulary, teaching math study skills, allowing students to have the same experiences, using math vocabulary within a meaningful context in instruction, immersing students in the language of math, making writing an integral part of math class, increasing the focus on the standards, employing children's literature to help students understand math terms, and utilizing reading strategies to teach vocabulary.

These solution strategies will be utilized by the teacher-researchers in their project. The results of these experiences will be discussed in Chapter four.

Project Objectives and Processes

As a result of increased instructional emphasis on mathematics vocabulary, during the time period of September 2000 to January 2001, the targeted fifth grade students will increase their understanding and comprehension of mathematical. The results will be measured by teacher-constructed vocabulary checklists, review of logs and journals, and evaluation of mathematical writing.

In order to accomplish the objective, the following processes are necessary:

1. Identify key vocabulary words that are essential in fifth grade mathematics.
2. Develop learning activities that foster the comprehension and communication of the essential vocabulary.
3. Administer assessment tools to determine growth and achievement in mathematical vocabulary.

Project Action Plan

WHEN	STRATEGY	PARTICIPANTS	WHY
Week 1	• Administer Student Survey • Implement the Use of Math Journals (on-going)	• Students in Site A & B • Students in Site A & B	• To determine validity • To increase awareness
Week 2	• Administer Student Questionnaire • Administer Vocabulary Checklist (pre) • Administer Teacher Survey	• Students in Site A & B • Students in Site A & B • 4^{th} & 5^{th} Grade Teachers in Site A & B	• To determine validity • To determine background knowledge • To determine validity
Week 3	• Administer Teacher Questionnaire • Administer Vocabulary Checklist (pre)	• 4^{th} & 5^{th} Grade Teachers in Site A & B • Students in Site A & B	• To determine validity • To determine background knowledge
Weeks 4 & 5	• Create Dictionary of Math Terms (on-going) • Teach Math Skills Through Children's Literature (on-going)	• Students in Site A & B • Students in Site A & B	• To increase use and comprehension of vocabulary • To increase use and comprehension of vocabulary
Week 6	• Practice ISAT Prompts (on-going) • Create Graphic Organizers (on-going)	• Students in Site A & B • Students in Site A & B	• To increase written communication of math understanding • To increase understanding of math
Weeks 7 – 13	• Above-Mentioned Strategies Continue	• Students in Site A & B	• To determine growth and achievement
Week 14 & 15	• Administer Vocabulary Checklists (post)	• Students in Site A & B	• To determine growth and achievement

Methods of Assessment

In order to assess the effects of the interventions, a vocabulary checklist will be administered to students in weeks two and three and again in weeks 14 and 15. Student-created Math Dictionaries will also be collected and reviewed for accuracy. In addition, students will use journals to record new concepts and ideas. Written explanations of word problems will be assessed using a rubric adapted from the Illinois Standards Achievement Test (ISAT).

CHAPTER 4

PROJECT RESULTS

Historical Description of the Intervention

This research project was designed to improve comprehension of content vocabulary in mathematics that interfered with mathematical issues and academic growth. The implementation of journals, math dictionaries, children's literature, and graphic organizers were selected to effect the desired changes. In addition to these strategies, extended response questions were used to elicit written explanations of mathematical concepts. In order to document the evidence of a poor understanding of mathematical vocabulary, a series of surveys and questionnaires were administered to both students and teachers prior to the implementation of the above-mentioned strategies. Mathematical vocabulary checklists were also administered to the students at the beginning of the implementation period to determine background knowledge. The same checklist was administered at the end of the intervention period to determine students' growth and achievement. The surveys, questionnaires, and checklists can be found in Appendices A through F, respectively.

Journals were used to encourage written expression of mathematical concepts, as well as to determine prior knowledge of key topics before their introduction. The use of math journals was implemented during week one and continued throughout the intervention period. Students were encouraged to write about various topics including, but not limited to, place value, division, multiplication, geometry, and problem solving. Journals were periodically checked to determine their effectiveness. A sample journal entry can be found in Appendix G.

In order to increase the use and comprehension of mathematical vocabulary students created and maintained dictionaries of math terms. Beginning in week four, students were given various mathematical terms to define in their own words, as well as provide an example or illustration in their math dictionary. This list of words was developed using the Grade 5 Word List from the 2000 Illinois Standards Achievement Test (ISAT) Math Sample Test. This master word list can be found in Appendix H. Students were encouraged to use their math dictionaries while completing assignments and in studying for tests. Dictionaries were periodically collected and checked for accuracy and completeness.

Children's literature books were also used to increase the use and comprehension of mathematical vocabulary. Starting in week four, a collection of math-related books were read and discussed with students. Each book was selected for its ability to introduce, reinforce, or review a particular mathematical concept. Many of these books lent themselves to the use of manipulatives, including food, which further helped to increase the understanding of the concept being presented. A comprehensive list of the books used can be found in Appendix I.

Original plans called for the use of graphic organizers beginning in week six of the intervention period. As graphic organizers were implemented in the classroom, it became apparent that the use of visual aids was more appropriate and beneficial. Many of the mathematical concepts originally targeted for the use of a graphic organizer were introduced by the means of a visual aid instead, such as a poster or diagram. Both the teacher and the students designed the visual aids that were then displayed in the classroom.

Extended response questions were used in order to increase written communication of mathematical understanding. These questions were patterned after the extended response questions found in the sample Grade 5 Math Illinois Standards Achievement Test (ISAT). Beginning in week six, students were given a mathematical problem to solve. In addition to solving the problem, students were required to explain in words what they did and why they did it. Students' responses were discussed and graded in class, as well as evaluated in small groups. Responses were evaluated using three categories based on the 5-point scale used for the ISAT, which ranges from zero to four. In order to meet or exceed state standards, students must receive a score of three or four in all three categories. The three categories are: mathematical knowledge, strategic knowledge, and written explanation. Mathematical knowledge involves the actual computation required to correctly solve the problem. Strategic knowledge involves the strategy or plan used to solve the problem. Written explanation involves the use of mathematical vocabulary in order to explain what was done and why it was done. The ISAT scoring rubric can be found in Appendix J. Sample extended response questions can be found in Appendix K.

Presentation and Analysis of Results

In order to evaluate the effectiveness of the interventions used for this project, two mathematics vocabulary checklists were used. Both checklists were developed using the Grade 5 Word List from the 2000 Illinois Standards Achievement Test (ISAT) Math Sample Test (Appendix H). The checklists can be found in Appendices E & F. These checklists were administered as both pretests and posttests in order to determine growth of mathematical vocabulary knowledge over the intervention period. Words were presented in alphabetical order to eliminate any word associations. Forty-three students from both targeted fifth grade classes were asked to check a box corresponding to their level of understanding for each vocabulary word: high, average, and low. They were also asked to provide a definition or example for each of the 69 words presented. These data are presented in Figures 5 and 6.

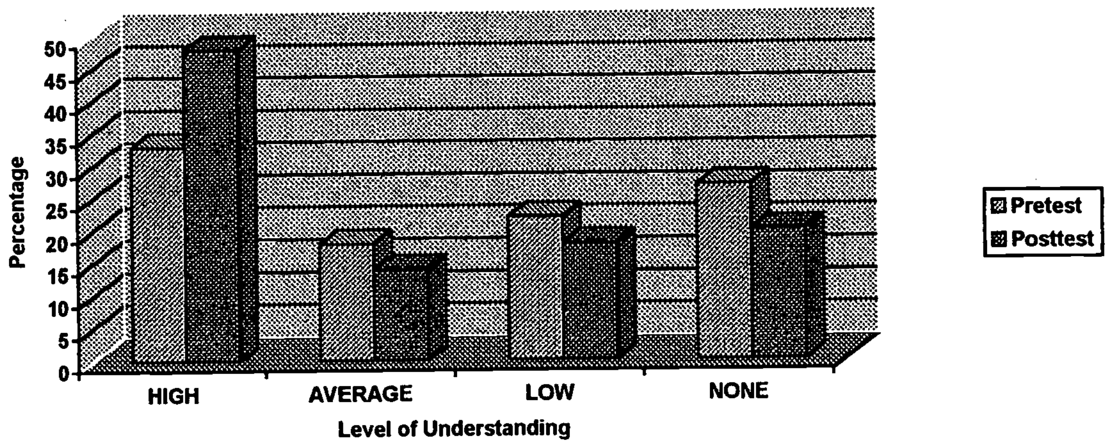

Figure 5. Math vocabulary checklist 1 – pre and post data.

An analysis of the students' initial level of understanding on the first math vocabulary checklist showed that 33 percent of the students exhibited a high understanding of the mathematics terms listed, whereas nearly half, 49 percent, of the students had low or no understanding of those same terms.

After reviewing the post data from the same vocabulary checklist, 48 percent of the students exhibited a high level of understanding of the vocabulary words. This is an increase of 15 percent. The percentage of students exhibiting low or no understanding of the vocabulary words decreased 11 percent, from 49 percent to 38 percent.

On the preliminary checklist, students had the most difficulty with the following basic terms: chord, congruent, mean, perpendicular, prime number, radius, similar, symmetry, vertex, and volume. However, on the final checklist, students exhibited an increased understanding of the following terms: mean, prime number, similar, symmetry, and vertex.

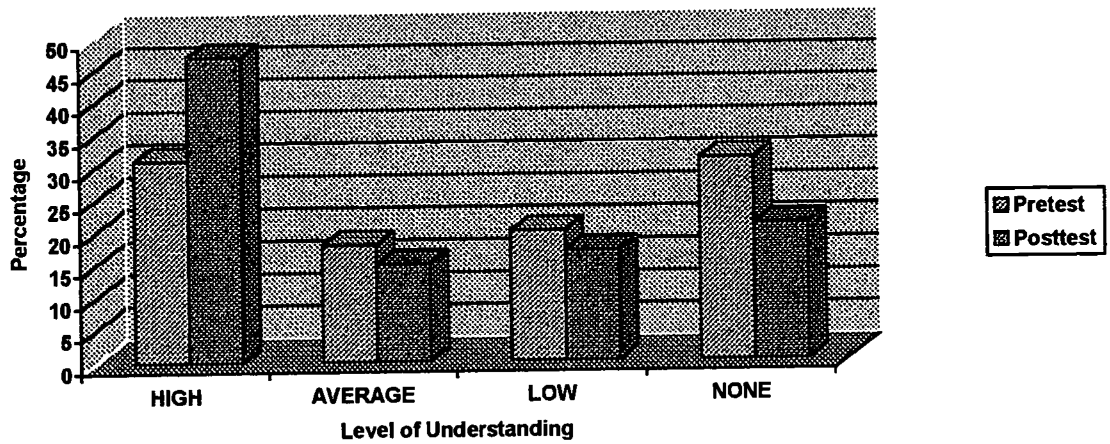

Figure 6. Math vocabulary checklist 2 – pre and post data.

An analysis of the students' initial level of understanding on the second math vocabulary checklist showed that 31 percent of the students exhibited a high understanding of the mathematics terms listed, whereas more than half, 51 percent, of the students had low or no understanding of those same terms.

After reviewing the post data from the same vocabulary checklist, 47 percent of the students exhibited a high level of understanding of the vocabulary words. This is an increase of 16 percent. The percentage of students exhibiting low or no understanding of the vocabulary words decreased 13 percent, from 51 percent to 38 percent.

On the preliminary checklist, students had the most difficulty with the following basic terms: equilateral triangle, flip, quadrilateral, prism, pyramid, polygon, rotation, slide, and turn. However, on the final checklist, students exhibited an increased understanding of the following terms: equilateral triangle, quadrilateral, prism, and rotation.

Conclusions and Recommendations

Based on the data presented in the previous section, the interventions appear to have had a positive effect on student comprehension of mathematics vocabulary words. The percentage of students exhibiting a high level of understanding on both vocabulary checklists increased, while the percentage of students exhibiting low or no understanding decreased. Students had difficulty with fewer of the vocabulary words on the final checklists than on the initial checklists. Lack of comprehension of vocabulary seemed to be less of an issue in the communication of mathematical knowledge than had previously been observed. All students appeared to increase their knowledge of mathematical vocabulary during the intervention period. This was noted through daily assignments, math journals, math dictionaries, written explanations of mathematical problems, and class discussions.

In conclusion, the teacher researchers believe that vocabulary development in any curricular area is dependent on student involvement. This is especially true in the area of mathematics, where the use of writing, children's literature, and student-created materials provide a means for increasing comprehension of key vocabulary terms. This comprehension is vital for students to be successful, since mathematics has such a large, subject specific vocabulary that needs to be mastered in order for the concepts of mathematics to be understood.

It was found that increased comprehension of mathematical vocabulary is dependent on varied methods of communication. Writing in the mathematics class, as in any curricular area, demonstrates a student's knowledge of the material being taught and allows an outlet for true authentic assessment. Using children's literature in the mathematics curriculum encourages students to use mathematical language, skills, and concepts. Presenting new concepts using this format allows for greater interest and enjoyment. Encouraging students to create their own materials, such as journals, dictionaries, and visual aids, enables students to be active participants in their mathematical learning. If literacy is the goal of education, it needs be the goal of mathematics education as well. Teachers can focus their energies on bringing all students to a greater awareness of the language of mathematics.

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APPENDICES

APPENDIX A

STUDENT SURVEY

MATH SURVEY – STUDENT

Please rank the following statements using the following scale:

SA = Strongly Agree **A** = Agree **D** = Disagree **SD** = Strongly Disagree

1. Math is my favorite subject.

   SA A D SD

2. The area I struggle with **the most** in math is solving word problems.

   SA A D SD

3. It would help me if I had a math dictionary with all the math words I need to know.

   SA A D SD

4. I need help in explaining how I solved my open-ended problems.

   SA A D SD

5. Math would be easy if I didn't have to read.

   SA A D SD

6. Sometimes in math I feel nervous, like I can't do the work.

   SA A D SD

Thank you for taking the time to complete this survey!

APPENDIX B

STUDENT QUESTIONNAIRE

Student Questionnaire – Math Vocabulary

Please answer the following questions as honestly and completely as you can.

Do you like math?

If you like math, why? If you don't like math, why?

What helps you understand math better?

What makes math hard for you?

What do you think teachers could do in math to make it easier for you to understand?

What topics did you cover in math last year? Please circle all that you remember.

addition	subtraction	multiplication
division	fractions	decimals
probability	ratios	bar graphs
line graphs	circle graphs	standard measurement (inches)
coordinate graphing	Metric measurement	2-dimensional geometry
3-dimensional geometry		

Thank you for taking the time to fill out this questionnaire!

APPENDIX C

TEACHER SURVEY

MATH SURVEY – TEACHER

Please rank the following statements using the following scale:

SA = Strongly Agree **A** = Agree **D** = Disagree **SD** = Strongly Disagree

1. I have difficulty in teaching my students how to solve word problems.
   SA A D SD

2. My students would benefit greatly by learning the vocabulary of math.
   SA A D SD

3. Teachers should use reading comprehension strategies to teach math story problems.
   SA A D SD

4. Students do not understand how to "explain" their work in an open-ended problem.
   SA A D SD

5. Students' math achievement is negatively affected by their lack of understanding of math terms.
   SA A D SD

6. Many of my students have "math anxiety" (feel nervous, low self-esteem with math).
   SA A D SD

Thank you for taking the time to complete this survey!
Please place it in my mailbox.

APPENDIX D

TEACHER QUESTIONNAIRE

Teacher Questionnaire – Math Vocabulary

Please answer the following questions as completely and accurately as possible.

What do you think are the strengths of our math program? Please list at least 3.

1.

2.

3.

What do you think are the weaknesses of our math program? Please list at least 3.

1.

2.

3.

Do you feel that our students have a strong math vocabulary? Why or why not?

Do you feel our program adequately introduces math vocabulary that our students should know? Why or why not?

Do you feel the lack of understanding of math vocabulary affects test scores? Explain.

What do you think we could do to increase the math vocabulary of our students?

OVER PLEASE ---- OVER PLEASE ---- OVER PLEASE ---- OVER PLEASE ----OVER PLEASE

Which of the following subjects did you cover in math last year? Please circle all that you covered.

addtion:	whole numbers	subtraction:	whole numbers
	decimals		decimals
	fractions		fractions
multiplication:	whole numbers	division:	whole numbers
	2 digit factors		1 digit divisors
	3 digit factors		2 digit divisors
	decimals		decimals
	fractions		fractions

2-dimensional geometry

triangles:	identification	quadrilaterals:	identification
	area formula		area formulas
	perimeter		perimeter
circles:	parts of a circle	other polygons:	identification
	area formula		area
	circumference		perimeter

3-dimensional geometry

prisms:	identification	pyramids:	identification
	surface area		surface area
	volume		volume
other polyhedrons			

equivalent fractions	reducing fractions	bar graphs
line graphs	circle graphs	ratios
probability	percents	measurement (Metric)
measurement (standard)	decimal place value	

Please return this to my mailbox by .
Thank you for taking the time to complete this questionnaire!
It will assist me in my Master's Degree Program!

APPENDIX E

VOCABULARY CHECKLIST ONE

MATH VOCABULARY CHECKLIST

Name:________________________ Date:________________________

My Level of Understanding				
Vocabulary Term	**High**	**Average**	**Low**	**Write a definition or example here.**
acute angle				
addends				
area				
chord				
circumference				
congruent				
diameter				
dividend				
divisor				
equation				
factor				
fraction				
Greatest Common Factor				
Least Common Multiple				
mean				
median				
mode				
obtuse angle				
parallel				

MATH VOCABULARY CHECKLIST

Name:_________________________ Date:_________________________

My Level of Understanding				
Vocabulary Term	**High**	**Average**	**Low**	**Write a definition or example here.**
perpendicular				
percent				
perimeter				
prime number				
product				
quotient				
radius/radii				
range				
ratio				
right angle				
similar				
sum				
symmetry				
variable				
vertex/vertices				
volume				

APPENDIX F

VOCABULARY CHECKLIST TWO

MATH VOCABULARY CHECKLIST

Name:________________________ Date:________________________

My Level of Understanding				
Vocabulary Term	**High**	**Average**	**Low**	**Write a definition or example here.**
2-dimensional				
3-dimensional				
acute triangle				
cone				
cube				
cylinder				
equilateral triangle				
flip				
heptagon				
hexagon				
isosceles triangle				
nonagon				
obtuse triangle				
octagon				
pentagon				
polygon				
quadrilateral				
rectangle				
rectangular prism				

MATH VOCABULARY CHECKLIST

Name:______________________ Date:______________________

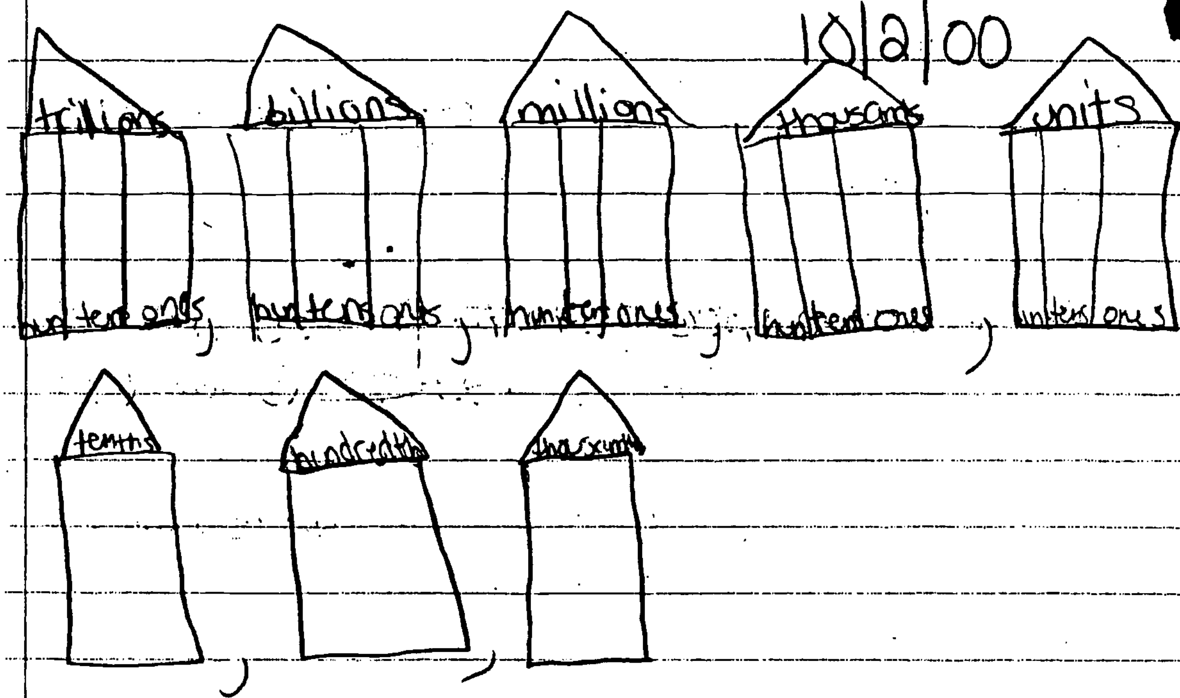
My Level Of Understanding				
Vocabulary Term	**High**	**Average**	**Low**	**Write a definition or example here.**
rectangular pyramid				
regular polygon				
reflection				
rhombus				
right triangle				
rotation				
scalene triangle				
slide				
sphere				
square				
trapezoid				
triangle				
triangular prism				
triangular pyramid				
turn				

APPENDIX G

SAMPLE JOURNAL ENTRIES

Mathland

10/2/00



10/3/00

Decimals are everywhere. When you use money, you are already using decimals. Decimals start big, and get small. Unlike the numbers left of the decimal point, which start small and get big. Decimals have these places: tenths, hundredths, thousandths, millionths, and so on.

10/11/00

What I know about decimals is that when you start after the decimal, you start big and end small. When you start before the decimal, you start small and get big. Also, the decimal stands for the word "and". We use decimals all the time in money. Also, the words after the decimal have to have the "ths", other wise it would be considered as a whole number.

11/27/00

What I know about multiplication, addition, and division in decimals is it is the same as regular division, subtraction, and multiplication just line up decimals so your number equals to a decimal.

Also, regular divison, sub., and multip. are when you put two numbers together and either find the difference, find a number times another, or the exact opposite (division)

APPENDIX H

ISAT GRADE FIVE MATH WORD LIST

Grade 5 Word List

Effective oral and written communication in the mathematics classroom is an essential component in helping students learn how to think mathematically and develop an awareness of how mathematics can be applied in many different contexts. In an effort to promote effective mathematics communication in the classroom, the Mathematics Advisory Committees compiled word lists to be included in this sample book. These lists contain words from items in the ISAT item bank. This word list should not be considered an official ISAT word list, nor is it intended to be used as a check list of any kind. Please note, each grade level assumes inclusion of all prior grade-level word lists.

2-dimensional
3-dimensional
acute angle
addends
angle (∠)
area
average
bar graph
base
centimeter (cm)
cents ($.00)
chord
circle/pie graph
circumference
column
combination
composite number
cone
cube
cubic units (^{3})
cylinder
degrees (°)
degrees Celsius (°C)
degrees Fahrenheit (°F)
diagonals
diagram
diameter
difference
dimensions
dividend
division (/)
divisor
edges
equation
equilateral triangle
estimate
even number
expression
faces
factors
flips
foot (ft)
fraction
gallon (gal)
greatest common factor
heptagon
hexagon
inch (in)
intersecting lines
irregular polygon
is approximately equal to (≈)
is congruent to (≅)
is equal to (=)
is greater than (>)
is less than (<)
is not equal to (≠)
is parallel to (||)
is perpendicular to (⊥)
is similar to (~)
isosceles triangle
kilogram (kg)
kilometer (km)
least common multiple
likely
liter (l)
mean
median
meter (m)
mile (mi)
milligram (mg)
millimeter (mm)
mode
multiply (* or •)
nonagon
obtuse angle
octagon
odd number
order of operations
ordered pair (x, y)
ounce (oz)
parallelogram
pattern
pentagon
percent (%)
perimeter
pint (pt)
point
polygon
pound (lb or #)
prime number
probability
product
quadrilateral
quart (qt)
quotient
radius/radii
range
ratio (: or "to")
rectangle
rectangular prism
rectangular pyramid
regular polygon
reflections
rhombus
right angle (∟)
right triangle
rotations
row
scale drawing
scalene triangle
slides
solve
sphere
square
square units (^{2})
sum
symbol
symmetry/symmetrical
table
ton (t)
trapezoid
triangle (Δ)
triangular prism
triangular pyramid
turns = rotations
units
variable
Venn diagram
vertex/vertices
volume
yard (yd)

APPENDIX I

BOOK LIST

BOOK LIST

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APPENDIX J

ISAT MATH SCORING RUBRIC

GRADE 5 "STUDENT FRIENDLY" MATHEMATICS SCORING RUBRIC

Score Level (How many points do you earn?)	MATHEMATICAL KNOWLEDGE: (Do you know it?)	STRATEGIC KNOWLEDGE: (How do you plan?)	EXPLANATION: (Can you explain it?)
4	♦ I show all my work to get the right answer and label it correctly. ♦ I use math terms correctly to show I understand how math works. ♦ I compute with no errors.	♦ I find all the important parts of the problem, and I know how they go together. ♦ I show all the steps I use to solve the problem. ♦ I completely show pictures, diagrams, models or computation if I use them in my plan.	♦ I write <u>what</u> I did and <u>why</u> I did it. ♦ If I use a drawing, I can explain all of it in writing.
3	♦ I use most math terms correctly. ♦ I make minor errors in computation.	♦ I find most of the important parts of the problem. ♦ I show most of the steps I use to solve the problem.	♦ I write mostly about <u>what</u> I did. ♦ I write a little about <u>why</u> I did it. ♦ If I use a drawing, I can explain most of it in writing.
2	♦ I know how to do parts of the problem, but I make major errors in computation and get a wrong answer. ♦ I give a wrong answer or only part of the answer.	♦ I find some of the important parts of the problem. ♦ I show some of the steps, but my plan is not clear.	♦ I write some about <u>what</u> I did or <u>why</u> I did it but not both. ♦ If I use a drawing, I can explain some of it in writing.
1	♦ I try to do the problem, but I don't understand it.	♦ I find almost no important parts of the problem. ♦ I show a plan that does not fit the problem.	♦ I write or draw something that doesn't go with my answer. ♦ I write an answer that is not clear.
0	♦ I don't try to answer the problem.	♦ I don't show a plan.	♦ I don't explain anything in writing.

APPENDIX K

SAMPLES OF EXTENDED RESPONSE QUESTIONS

Problem of the Week

Name ______________________ Date ______________

Your neighbor has a whole pile of bricks to move. She says she will pay you to move them and asks if you want to get paid by the hour (at $3 an hour) or by the brick (at 3¢ a brick). There are 650 bricks. It takes you 1 minute to move 2 bricks and return for more. Which is the better deal?

Problem of the Week

Name ______________________ Date ______________

Four students took the same 4 tests. The scores for each student are listed below.

Student	Test 1	Test 2	Test 3	Test 4
Andy	100%	90%	80%	90%
Barb	95%	92%	95%	90%
Cole	87%	88%	70%	95%
Diane	60%	100%	100%	60%

Based on these scores, calculate which student did the best overall. Explain in words the steps you followed and **why** you think the student you picked did better than the other students.

For this response, make sure that you:
show all of your work in solving the problem,
clearly label your answer,
tell in words <u>how</u> you solved the problem,
tell in words <u>why</u> you did the steps you did to solve the problem, and
write as clearly as you can.

Problem of the Week

Name ____________________ Date ______________

Each day Mr. Anderson brings candy to his class. The chart below shows the number of pieces of candy he brought each day and the number of pieces of candy he gave to his students each day. How many pieces of candy did he have left at the end of the week? Show all of your work.

Day of the Week	# Pieces Brought In	# Pieces Given Out
Monday	7	5
Tuesday	4	5
Wednesday	5	3
Thursday	4	6
Friday	3	2

Problem of the Week

Name ____________________ Date ______________

Al left a secret message for Guy on one of the pages of their math book. Guy knows that the number of the page the message is written on is less than 160, because their are 160 total pages in the book. Al also told him that the page number is a 3-digit number, that one of the digits is 4, and the total of all three digits in the number is 12. On what page is the secret message? How do you know? Show all of your work.

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