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Investigation of the Relationship Between Language & Mathematics in Regards to Problem Solving

Heather A. Grant

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Investigation of the Relationship Between
Language & Mathematics in Regards to Problem Solving
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BY

Heather A. Grant

THESIS

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Investigation of the Relationship Between
Language & Mathematics in Regards to Problem Solving


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Running head: LANGUAGE & MATHEMATICS

Abstract

While previous research has established language as a component of mathematical performance (Kintsch, 1988; Simon, 1985), none have identified a relationship between language and mathematics. This study was conducted to examine the relationships between language and mathematical abilities, specifically problem solving abilities and concept knowledge.

The subjects consisted of 29 fifth-grade students selected from an elementary school in central Illinois. These students were not receiving special education services. Each subject was administered the Test of Problem Solving (Zachman, et al., 1984) to assess the subjects' ability to utilize reasoning skills and expressive language to solve situational problems; and The WORD Test-R (Elementary) (Huisinigh, et al., 1990) to assess the subjects' ability to identify and express important semantic elements of their lexicon, such as synonyms and multiple meaning words. To assess mathematical problem solving abilities and mathematical concept knowledge, scores were obtained from the "Mathematical Problem Solving" and "Mathematical Concepts" subtests of the subjects' Iowa Tests of Basic Skills.

Results of testing revealed several significant positive relationships. First, a significant relationship

was found between linguistic problem solving abilities and linguistic concept knowledge. In addition, a significant correlation was found between mathematical problem solving abilities and mathematical concept knowledge. Linguistic concept knowledge was also found to be significantly related to both mathematical problem solving abilities and mathematical concept knowledge. However, linguistic problem solving abilities were not found to be significantly correlated with either mathematical problem solving abilities or mathematical concept knowledge.

These findings suggest that the linguistic conceptual knowledge evaluated on The WORD Test-R (Elementary) (Huisinigh, et al., 1990) has a strong positive relationship with mathematical performance. In addition, results signified that linguistic concept knowledge is a reliable indicator of performance in the areas of linguistic problem solving, mathematical problem solving, and mathematical concept knowledge.

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Chapter 1

Introduction

Language abilities have been recognized in recent literature as having an influence on academic performance. Reading comprehension, for instance, has been found to require the use of semantic and syntactic knowledge. In order to comprehend a written text or narrative, word identification, inferencing and imagery of verbal descriptions are utilized to form a mental representation of the information (Kintsch, 1988). In addition, Feagans and Appelbaum (1986) found that children's narrative abilities were an accurate predictor of academic performance.

Word problems are similar to narratives in that both require students to incorporate and relate linguistic information to their present knowledge. Regarding narratives, the knowledge concerns characters and actions, whereas in word problems, the knowledge concerns the problem. Therefore, language abilities are also essential to successful academic performance in mathematics. In order for students to solve mathematical problems, they must have computational, cognitive, and linguistic knowledge (Simon, 1985).

While the linguistic component of mathematical word problems has been examined by researchers, a relationship between language abilities and mathematical abilities has not been established. Further, although linguistic

knowledge and abilities have been considered variables in word problem solving abilities, they have not been proven to be predictors of mathematical success. To examine this possible relationship, a pilot study was conducted which investigated the language and mathematical abilities, particularly problem-solving and concept knowledge, of three subjects enrolled in fourth grade (Grant, 1994). Although sample size was limited, results suggested the existence of a relationship between students' language abilities and mathematical abilities. Therefore, the purpose of the present study was to examine the existence of a relationship between language abilities and mathematical abilities using a larger, and therefore, more reliable sample.

Chapter 2

Review of Literature

Researchers have identified language abilities as a component in academic performance. Reading comprehension and mathematical performance, for instance, have been found to be influenced by linguistic abilities (Kintsch, 1988; Simon, 1985). Regarding reading comprehension, Kintsch (1988) stated:

"Discourse comprehension, from the viewpoint of a computational theory, involves constructing a representation of a discourse upon which various computations can be performed, the outcomes of which are commonly taken as evidence for comprehension."
(p.163)

The development of mental representations involves linguistic processes, such as word identification, an inference mechanism, and spatial imagery. Word identification allows students to recognize a word and words related to it, while the inference mechanism permits students to presume information based on given facts. In addition, students can imagine verbal descriptions of places when using spatial imagery processes (Kintsch, 1988).

It is this knowledge of semantics, syntax, and spatial relations that influences the mental representations students produce. How the knowledge is applied when reading depends on the type of processing, top-down or bottom-up, which students employ (Kintsch, 1988).

Top-down processing refers to conceptually driven

processing based on semantic knowledge. Through top-down processing, well-developed semantic schemata and all its subschemata are utilized (De Corte, Verschaffel, & De Win, 1985; Wallach & Butler, 1984). When students use top-down processing for reading comprehension, their knowledge influences context interpretations. Children who utilize top-down processing for word identification can recognize the appropriate meaning of ambiguous information and repress inappropriate interpretations. When inferencing, students can ignore irrelevant or extraneous information (Kintsch, 1988).

Students who do not use top-down processing employ bottom-up processing. Bottom-up processing refers to text-driven processing. Children with less developed semantic schemata depend more on bottom-up processing. While processing information, these students examine each piece of the material, or subschemata, to develop a complete representation. Further, they are not as likely to ignore the extraneous information in the text (De Corte, et al., 1985).

While reading comprehension requires use of linguistic knowledge, such as inferencing, word identification, and imagery when processing language, mathematical performance also requires use of linguistic, as well as computational and cognitive, knowledge (Simon, 1985). Development of mathematical abilities has been reflected in the linguistic

development theory. According to the linguistic development theory, children's abilities to solve mathematical problems, particularly word problems, are based on semantic and logico-mathematical knowledge. Linguistic structures employed in word problems must correspond with the children's present conceptual forms. In addition, children must develop logico-mathematical knowledge of set relations represented as schemata. Therefore, deficits in mathematical performance result from semantic deficiencies, logico-mathematical deficiencies, or both (Cummins, et al. 1988).

Kintsch and Greeno (1985) developed a model that reflects the knowledge structures and strategies used to formulate mental representations needed for comprehending and solving mathematical word problems. Their model considers the semantic and syntactic difficulties children encounter when solving mathematical word problems. They believed that students obtain a unique set of strategies that they use to build representations of mathematical texts. These strategies are the result of increased experience in answering mathematical questions.

The model by Kintsch and Greeno (1985) involved forming a mental representation of the problem by extracting relevant information from the text base needed for appropriate computations. When students assemble a problem model, they also infer details needed to solve the problems

that are not in the text base and omit given material not needed for computation. In addition, mental representations and problem solutions are constructed using comprehension strategies that employ knowledge schemata.

The comprehension strategies utilize cues based on information and key words in the text. The strategies allow students to connect the semantic meaning of certain phrases, such as "have more than," "have less than," and "have altogether," with the appropriate problem computation. For instance, when presented with "have less than" in the word problem, children are cued to find the difference between given quantities. These specific cues and strategies in the model permit children who use bottom-up processing to comprehend word problems by excluding the extraneous and ambiguous information and highlighting the relevant (Kintsch and Greeno, 1985).

Many researchers have supported the linguistic development theory and Kintsch and Greeno's (1985) model through their own examinations of the linguistic components involved in solving mathematical word problems. De Corte, et al. (1985) examined the use of top-down and bottom-up processing in solving mathematical word problems. They also studied the effects that rewording mathematical word problems had on students' computations. Their theoretical framework was that the first step in solving a problem was to process the text through a combination of bottom-up and

top-down processing. While word problems used in schools are often ambiguous and less explicitly stated, students who utilized top-down processing could compensate for the ambiguities because of a strong semantic base. Children with semantic deficits used bottom-up processing to interpret the problems.

The researchers hypothesized that by rewording word problems to make semantic information less ambiguous without changing the semantic and conceptual structures, children would correctly comprehend and produce solutions. It was also felt that second graders would better utilize top-down processing than first graders because of a more developed semantic schemata.

Children involved in the study conducted by De Corte, et al. (1985) included 89 first grade students and 84 second grade students. The students were presented with six problems worded as most often found in arithmetic books, and six reworded to highlight semantic relations. Two problems from each set were change problems that required students to increase and decrease the value of a quantity. Two combine problems in each set required students to consider static relations among quantities either together or separately. Finally, compare problems made up the remaining two problems in each set. These problems requested that students compare amounts and find their difference (De Corte, et al., 1985).

Results revealed that children performed significantly

higher on reworded problems than on standard worded problems. This evidence supported the hypothesis that rewording facilitated children's abilities to comprehend and solve word problems by compensating for the semantic deficits. By rewording problems to eliminate the ambiguities, children's comprehension and solution abilities were enhanced. Findings also suggested that children who were not as experienced at solving word problems as older children had not developed the semantic schemata needed to utilize top-down processing. Because younger students had less developed semantic schemata, they employed bottom-up processing. Their processing abilities did not compensate for the ambiguities and extraneous information, and would probably benefit from rewording strategies.

The impact of linguistic knowledge was also investigated by Cummins, et al. (1988). They conducted a study in which linguistic knowledge was found to have an impact on students' comprehension and solution of word problems. The goal of the study was to identify students' problem representations and interpretations. It was hypothesized that students' solution errors would represent correct solutions to misunderstood problems. It was also predicted that performance would be positively influenced by linguistic restructuring of word problems.

Results were obtained by examining the solution accuracy on verbal problems and numeric problems plus

subjects' structural recall of the problems. Results revealed that the students performed higher on numeric problems than word problems. Regarding structural recall, results revealed that children rephrased difficult, complex problems to simpler problem structures to fit their semantic knowledge. Further, conceptual errors were actually correct responses to misunderstood word problems.

Davis-Dorsey, Ross, and Morrison (1991) did further research on the role of rewording in comprehension and solution of word problems by examining the influence of context personalization. Based on the information presented by De Corte et al, (1985), Davis-Dorsey, Ross, and Morrison (1991) proposed that children who had difficulty solving problems would profit from both rewording and context personalization. Personalization referred to using information in the word problem that was related to the specific student.

In order to obtain the personal information needed for the problems, students answered a questionnaire regarding favorite movies, food, friends, and pets. This information then replaced certain referents in standard-context problems. Rewording was based on portions of the rewording model used by De Corte, et al. (1985). These problems were then divided into groups of four wording-context variations. The variations included standard wording-standard context(SS), standard wording-personalized context(SP),

rewording-standard context(RS), and, finally, rewording-personalized context(RP). Findings revealed that students performed higher on personalized problems than on standard problems and higher on reworded problems than standard problems.

While previous researchers mentioned examined only the semantic component of word problems, Linville (1976) hypothesized that the complexity of syntax and vocabulary of word problems impacted fourth grade students' performances. In addition, he suggested that there would be no difference between the mathematical test scores of males and females when syntax and vocabulary complexity were varied. Performance was determined by reading comprehension scores on the Iowa Tests of Basic Skills and scores obtained from four tests, each including 10 word problems varying in syntactic and vocabulary complexity, administered by the researcher.

Results were acquired through an analysis of variance and revealed no significant difference between the test scores for boys and girls. However, results did reveal a significant difference regarding students' reading achievement levels and their competence in word problem solutions. Results suggested that syntax and vocabulary level impacted students' abilities to solve mathematical word problems.

Although many researchers have explored language

knowledge as a component in solving mathematical word problems, the relationship between language abilities and mathematical abilities has not been investigated. In an attempt to examine a relationship between language abilities and mathematical abilities regarding problem solving and concept knowledge, this examiner conducted a pilot study using three fourth grade students. Language abilities were assessed through the Test of Problem Solving (TOPS) (Zachman, Jorgensen, Huisinigh, & Barrett, 1984) and The WORD Test-Revised (Elementary) (Huisinigh, Barrett, Zachman, Blagden, & Orman). Mathematical abilities were determined by percentile ranks obtained from each student's Iowa Tests of Basic Skills administered within the school setting. The results indicated the existence of a relationship between the subjects' abilities to use language to solve verbal situational problems and their abilities to use mathematics to solve word problems. An inverse relationship was found to exist, however, between subjects' language concept knowledge and mathematical concept knowledge. Due to small sample size, further research is needed to validate these findings. Therefore, the present study was designed to investigate the relationships between language abilities and mathematical abilities. The following research questions were addressed:

1. Does a relationship exist between language abilities used to solve situational problems and

mathematical abilities used to solve word problems?

2. Does a relationship exist between language concept knowledge and mathematical concept knowledge?

Chapter 3

METHODS

Subjects

Twenty-nine normal-functioning students were selected from the fifth grade at an elementary school in Charleston, Illinois. In order to eliminate gender differences as a variable in mathematical performance, subjects were selected based on Linville's (1976) findings that no significant differences existed between the mathematical word problem scores of males and females in fourth grade. Consideration was also given to Marshall and Smith's (1987) findings that, while girls performed significantly better than boys on word problems in third grade, differences in mathematical performance due to gender disappeared by sixth grade. Therefore, subjects were selected early in the fall from fifth grade, while mathematical scores were obtained from each corresponding subject's fourth grade records of the Iowa Tests of Basic Skills.

A letter explaining the research study was sent to the elementary school to recruit subjects (Appendix A). Parents granted written permission for their child to participate in the study and, further, agreed to provide the investigator with their child's fourth grade mathematical percentile ranks from the Iowa Tests of Basic Skills (Appendix B). Students currently receiving special education services were

not included in the study.

Materials

A Maico Model MA-20 portable audiometer was used to conduct peripheral hearing screenings. Following the peripheral screenings, the Test of Problem Solving (TOPS) (Zachman, Jorgensen, Huisingh, & Barrett, 1984) and The WORD Test-R (Elementary) (Huisingh, Barrett, Zachman, Blagden, & Orman, 1990) were administered. The Test of Problem Solving (TOPS) (Zachman, et al., 1984) was administered to assess the subjects' ability to utilize reasoning skills and expressive language to solve situational problems. The test provides standardized information on children 6 to 12 years of age. The WORD Test-R (Elementary) (Huisingh, et al., 1990) was administered to examine the subjects' ability to identify and communicate critical semantic elements of their lexicon, such as synonyms, semantic absurdities, and multiple definitions. This test provides standardized information on children ages 7 years, 0 months through 11 years, 11 months.

The Iowa Tests of Basic Skills are administered annually to students in grades second or third through ninth grade to measure reading, language, mathematics, and work-study skills (Preliminary, 1986). The "Mathematics Concepts" portion of the test evaluates the subjects' understanding of quantitative processes, such as solutions

of equations and recognizing types and parts of geometric figures. The "Mathematics Problem Solving" portion of the test evaluates the subjects' ability to solve mathematical word problems (The New Riverside Basic Skills Assessment Program K-12, 1985).

Procedures

Approval for the use of human research subjects was obtained from the Human Resource Office at Eastern Illinois University (Appendix C). A letter explaining the research study and seeking assistance for the recruitment of subjects was sent to fifth grade teachers at Jefferson Elementary School in Charleston, Illinois (Appendix A). Subjects were chosen from those whose parents signed and returned the permission form.

Each subject was evaluated during a one-hour individual session that included a peripheral hearing screening and administration of the Test of Problem Solving (TOPS) (Zachman, et al., 1984) and The WORD Test-R (Elementary) (Huisinigh, et al., 1990). All subjects passed a peripheral hearing screening. Passing criteria required appropriate responses to bilateral pure tone air conduction at 25 dB, not exceeding 35 dB, for the frequencies of 500, 1000, 2000, and 4000 Hz. Immediately following the hearing screening, those subjects who passed were administered the Test of Problem Solving (TOPS) (Zachman, et al., 1984) and The WORD

Test-R (Elementary) (Huisinigh, et al., 1990). Test items were administered verbally by the examiner. Verbal responses obtained from the subjects were recorded verbatim. Testing was completed in a relatively quiet room within the school after regular instruction hours or at the Eastern Illinois University Speech-Language-Hearing Clinic.

The Iowa Tests of Basic Skills were administered to the subjects by their classroom teachers in February, 1994. Test instructions were presented to the students verbally, while actual test items were presented through written text. Student response modality was multiple choice. The tests were mechanically scored by The Riverside Scoring Service (Hieronymous, Hoover, & Lindquist, 1986) and scores were provided to the students' parents by the school. Mathematical percentile ranks were provided to the examiner by each subject's parents.

Analysis

A Pearson (r) correlational analysis (Glass & Hopkins, 1984) was employed to examine percentile rank scores gathered from the Test of Problem Solving (Zachman, et al., 1984), The WORD Test-R (Elementary) (Huisinigh, et al., 1990), and Iowa Tests of Basic Skills administered to each subject. Correlational coefficients were established to reflect five relationships: 1) between the subjects' language problem solving abilities and linguistic concept

knowledge; 2) between the subjects' mathematical problem solving abilities and mathematical concept knowledge; 3) between the subjects' language problem solving abilities and mathematical problem solving abilities; 4) between their linguistic concept knowledge and mathematical concept knowledge, and 5) between their linguistic concept knowledge and mathematical problem solving skills.

To determine interjudge reliability, ten percent of the tests administered were rescored by a graduate student in Communication Disorders and Sciences. Confirmation of scored responses was 98%.

Chapter 4

RESULTS

A Pearson (r) correlational analysis (Glass & Hopkins, 1984) was utilized to examine the relative strength of percentile scores obtained on the Test of Problem Solving (TOPS) (Zachman, et al., 1984), The WORD Test-R (Elementary) (Huisinigh, et al., 1990) to predict percentile scores on the Iowa Tests of Basic Skills. Due to the percentile ranks being normally distributed and no tied ranks existing, the Pearson (r) was chosen as the appropriate statistical method. An $N=29$ was used to establish correlational coefficients which reflected five linguistic and/or mathematical relationships. The first correlational coefficient, which examined a linguistic relationship, was derived from the Total Test percentile rank on the Test of Problem Solving (TOPS) (Zachman, et al., 1984) and Total Test percentile rank on The WORD Test-R (Elementary) (Huisinigh, et al., 1990). The second correlational coefficient, which examined a mathematical relationship, was derived from the percentile rank of the "Mathematical Problem Solving" subtest and percentile rank of the "Mathematical Concepts" subtest of the Iowa Tests of Basic Skills. These relationships are summarized in Table 1.

Table 1. Correlation coefficients for language and mathematics

	<u>Correlation</u>	<u>R Squared</u>	<u>Prob /r/=0</u>
Language (<u>TOPS</u> & <u>WORD-R</u>)	0.6110	0.3633	0.000
Mathematics (<u>ITBS</u> Subtests)	0.7607	0.5787	0.000

A probability of $p < .05$ indicated a significant positive correlation between linguistic problem solving scores and linguistic concept knowledge. In addition, a significant positive correlation was found between mathematical problem solving scores and mathematical concept knowledge.

In order to reflect a relationship between problem solving abilities, a third correlational coefficient was derived from the Total Test percentile rank on the Test of Problem Solving (TOPS) (Zachman, et al., 1984) and percentile rank of the "Mathematical Problem Solving" subtest of the Iowa Tests of Basic Skills. The fourth correlational coefficient, which reflected a relationship between concept knowledge, was derived from the Total Test percentile rank on The WORD Test-R (Elementary) (Huisinigh, et al., 1990) and percentile rank of the "Mathematical Concepts" subtest of the Iowa Tests of Basic Skills. These relationships are summarized in Table 2.

Table 2. Correlation coefficients for problem solving and concept knowledge.

	<u>Correlation</u>	<u>R Squared</u>	<u>Prob /r/=0</u>
Problem Solving (Linguistic & Mathematical)	0.2612	0.0682	0.171
Concept Knowledge (Linguistic & Mathematical)	0.5653	0.3196	0.001

A probability of $p < .05$ indicated that a significant positive relationship between linguistic problem solving abilities and mathematical word problem solving abilities did not exist. However, the relationship between linguistic concept knowledge and mathematical concept knowledge was significant. That is, test scores measuring children's knowledge of concepts, such as multiple meaning words and definitions, was found to predict test scores measuring mathematical concept knowledge needed to perform fractions and solve equations.

The fifth, and final, correlational coefficient was computed from the Total Test percentile rank on The WORD Test-R (Elementary) (Huisinigh, et al., 1990) and percentile rank of the "Mathematical Problem Solving" subtest of the Iowa Tests of Basic Skills. This coefficient is summarized in Table 3.

Table 3. Correlation coefficient for linguistic concept knowledge and mathematical problem solving.

	<u>Corre.</u>	<u>R Squared</u>	<u>Prob/r/=0</u>
Linguistic Concept Knowledge & Mathematical Problem Solving	0.4184	0.1751	0.024

A significant positive correlation was indicated by a probability of $p < .05$ between linguistic concept knowledge and mathematical problem solving abilities. As linguistic concept knowledge scores increased, so did mathematical problem solving scores. This signified that children's abilities to utilize linguistic concept knowledge to perform such tasks as defining and differentiating terms, correlated with their abilities to use word identification skills and inferencing to comprehend mathematical word problems.

In conclusion, results of the correlational analysis revealed that linguistic concept knowledge, as measured by The WORD Test-R (Elementary) (Huisinigh, et al., 1990), was significantly correlated with linguistic problem solving, mathematical concept knowledge, and mathematical problem solving. Table 4 displays these correlations.

Table 4. Correlation coefficients with linguistic concept knowledge.

	<u>Correlation</u>	<u>R Squared</u>	<u>Prob /r/=0</u>
1) Linguistic Problem Solving	0.6110	0.3733	0.000
2) Mathematical Concepts	0.5653	0.3196	0.001
3) Mathematical Problem Solving	0.4184	0.1751	0.024

Chapter 5

Discussion

Previous researchers have shown that language knowledge is a necessary component in the ability to solve mathematical word problems (Simon, 1985; De Corte, et al., 1985; Cummins, et al., 1988; Davis-Dorsey, Ross, & Morrison, 1991; Linville, 1976). This linguistic component has also been explored by Kintsch and Greeno (1985) in a mathematical problem solving model which includes word identification, inferencing, and spatial imagery. The purpose of this study was to determine if a relationship existed between linguistic and mathematical problem solving abilities and semantic concept knowledge.

Results of the study revealed significant relationships between language and mathematical abilities. Significant relationships were found between tests administered to measure problem solving abilities and concept knowledge, specifically, 1) the Test of Problem Solving (TOPS) (Zachman, et al., 1984) and The WORD Test-R (Elementary) (Huisinigh, et al., 1990), and 2) the "Mathematical Problem Solving" and "Mathematical Concepts" subtests of the Iowa Tests of Basic Skills. In addition, probabilities of $p < .05$ indicated that linguistic concept knowledge was significantly related to both mathematical problem solving abilities and mathematical concept knowledge.

Linguistic concept knowledge, as measured by The WORD

Test-R (Elementary) (Huisinigh, et al., 1990), appeared to be a reliable predictor of performance on mathematical problem solving and mathematical concept knowledge tasks. Although linguistic concept knowledge was found to be a predictor of mathematical problem solving skills, a significant relationship between linguistic problem solving abilities and mathematical problem solving abilities was not observed. These relationships are summarized in Table 5.

Table 5. Relationships between language abilities and mathematical abilities.

<u>TOPS</u>	vs.	<u>WORD-R</u>	*
MPS	vs.	MCK	*
<u>TOPS</u>	vs.	MPS	NS
<u>TOPS</u>	vs.	MCK	NS
<u>WORD-R</u>	vs.	MCK	*
<u>WORD-R</u>	vs.	MPS	*

* indicates significant positive relationship
 NS indicates nonsignificant relationship

MPS = Mathematical Problem Solving
 MCK = Mathematical Concept Knowledge

The significant relationships found in the study revealed that linguistic performance on The WORD Test-R (Elementary) (Huisinigh, et al., 1990) was indicative of mathematical performance. The WORD Test-R (Elementary) (Huisinigh, et al., 1990) was designed to measure children's comprehension and application of words and their meanings

through semantic features. In order to achieve word mastery, children must develop abilities to categorize, define, verbally reason, categorize, classify, and differentiate word meanings. For instance, for children to have mastered the word "change," they must be able to identify that it has more than one meaning and define it as "alter" or "coins." In addition, the ability to differentiate word meanings requires children to compare and contrast definitions of mastered words and words related to them. The WORD Test-R (Elementary) (Huisinigh, et al., 1990) also assesses word mastery by evaluating how children sort and classify words by semantic features. Results of the test reflect how children deal with the language demands placed on them during classroom activities, specifically mathematical exercises.

The relationship between linguistic concept knowledge and mathematical concept knowledge is reflected in mathematical tasks such as equations and fractions. According to Orman (1993), children are often confronted with multiple meaning words when completing equations. For instance, when computing the equation $5-3$, children are asked to identify "what is left." In order to formulate a correct response, they must identify the appropriate meaning of "left" as "remaining" rather than as a direction. Application of the inappropriate definition of "left" may result in children identifying what is on the left side of

the equation and, therefore, completing it with such answers as "8" or "5 and 3." This same mathematical concept knowledge is also applied in situational activities in which linguistic concept knowledge is employed. When children follow a recipe for making oatmeal raisin cookies, for example, the directions may include "add the raisins." For the directions to be interpreted correctly, children need to identify the appropriate definition of the word "add" and add all the raisins to the other ingredients rather than lining the raisins up in a row by adding one raisin to the next.

In addition to defining and selecting appropriate meanings when confronted with multiple meaning words in mathematical equations, children frequently must differentiate linguistically similar terms in fractions. For instance, when students are told to find the "numerator", they must differentiate this term from "denominator." While both terms refer to the two components of a fraction, students must identify one as "the number of parts taken" (numerator) and the other as "the number of parts in the whole" (denominator) in order to correctly comprehend a fraction.

Children's mathematical problem solving abilities were also significantly related to their linguistic concept knowledge. Results of the present study indicated that children's linguistic concept knowledge had a significant

relationship with mathematical problem solving performance. These findings supported the linguistic development theory (Cummins, et al., 1988) which suggests that the ability to solve mathematical word problems is based on semantic knowledge. Further, for children to successfully complete mathematical word problems, the linguistic structures of the word problems must parallel, or correlate, with the children's linguistic conceptual knowledge.

The model for solving mathematical word problems discussed by Kintsch and Greeno (1985) was also substantiated by this study's findings. In order to complete mathematical word problems accurately, the model suggests that students must be able to extract relevant and omit extraneous information, infer details, and accurately identify key words needed for the computation in the text. Each of these skills was associated with linguistic concept knowledge. When children remove relevant information needed for the computation, they also sort and classify words by the important semantic features of the related words. In other words, they identify statements or phrases which are associated with the computation or question asked. For example, in the word problem, "Bob had three large, red apples; Dan had five juicy, green apples; How many more apples did Dan have than Bob?", children should identify the critical elements of the text as "Bob-three," "Dan-five," and "how many more did Dan have." The remaining words are

extraneous and not required to complete the computation. Further, the phrase "have more than" is classified as one indicating subtraction.

Linguistic concept knowledge in the form of verbal reasoning skills was also related to the ability to infer details in a mathematical word problem. In the word problem mentioned above, students should employ reasoning skills to determine the accuracy of a solution. For instance, knowing that Bob had less than five apples and Dan had exactly five apples, students should infer that the answer must be less than five apples.

A final component in the mathematical word problem solving model (Kintsch & Greeno, 1985) is word identification. Word identification in problem solving can be associated with the linguistic ability of defining. While word identification refers to identifying key words in a problem text and connecting semantic meaning to key phrases, defining involves identifying appropriate word meanings based on related words (Huisinigh, et al., 1990). As discussed earlier, when students read the phrase "have more than" in a word problem, accurate word identification requires them to relate it to a subtraction computation. Further, when reading a recipe, mathematical problem solving skills and linguistic concept knowledge allow children to select the appropriate meaning of the phrase "add the raisins" so the raisins are added to other ingredients,

rather than to each other.

The relationship between the linguistic concept knowledge of defining and the mathematical word problem solving ability of word identification also further substantiated the findings of De Corte, et al. (1985), Cummins, et al. (1988), and Davis-Dorsey, Ross, and Morrison (1991). Studies by these researchers suggested that changes in wording facilitated accurate defining and selection of appropriate words needed to identify accurate computations. For instance, De Corte, et al. (1985) found that rewording of semantically complex word problems decreased the use of ambiguous terms, such as "add," and increased accurate word identification. Children responded positively to this highlighting of the critical semantic features of the word problem.

Results of the present study convey many implications for speech-language pathologists in the areas of assessment and remediation in language and mathematics. While teachers typically concentrate on students' computational skills and cognitive development, results indicate that speech-language pathologists may have a role in teaching the linguistic component of mathematics. A collaborative teaching approach to mathematics may enhance students comprehension and application of concepts and problem solving abilities. In addition, this collaborative teaching may prevent future mathematical and language problems in normal and at-risk

children through early identification. While regular education teachers continue to concentrate on the computational skills required to solve word problems, speech-language pathologists can address the language components, such as defining, reasoning, and categorizing.

In addition, the significant relationship between linguistic concept knowledge and both mathematical concept knowledge and mathematical problem solving found in this study indicated that The WORD Test-R (Elementary) (Huisinigh, et al., 1990) may be a useful instrument for the speech-language pathologist to assess language concept knowledge as well as predict mathematical performance. While The WORD Test-R (Elementary) (Huisinigh, et al., 1990) is typically administered with a focus on linguistic concept knowledge, utilization of this diagnostic instrument may provide speech-language pathologists with a more complete and thorough assessment of the academic potential for a student, rather than only language skills. With regards to remediation of language and/or mathematical deficits, knowing that a relationship exists between language and mathematical abilities allows speech-language pathologists to consider including mathematical activities in therapy to target linguistic deficits. In addition, linguistic concept knowledge can be addressed in the classroom by teachers and speech-language pathologists to compliment mathematics.

Finally, the significant relationship between

linguistic concept knowledge and mathematical concept knowledge and problem solving abilities suggests that students' abilities to comprehend and complete mathematical word problems may be affected by another component, "metamathematics." While "metalinguistics" refers to the ability to think about language, such as word definitions and inferences, and "metacognition" refers to the knowledge of one's own thought processes and reasoning (Owens, 1988), "metamathematics" can refer to the ability to think about the components of mathematics. Students who are not aware of word identification and inference processes will fail to address these linguistic aspects when trying to comprehend and solve mathematical problems, including equations, fractions, and word problems. For example, students who do not recognize the possibility that word problems may contain ambiguous terms, will not consider other meanings of the words. Instead, these students may complete an equation by stating what is on the "left" side of the equal sign rather than the quantity remaining.

Considering the implications of the present study, further research is needed to validate the findings. Whereas this study was conducted using normal-functioning subjects, future research may consider investigating the linguistic/mathematical relationship among learning disabled and/or language disordered children. In addition, a learning effect may be reflected in results in that the Iowa

Tests of Basic Skills were administered in February, 1994, and the linguistic tests were administered between September through mid-November, 1994. A more consistent, condensed time frame for all testing may alter the results.

In conclusion, the present study provides a foundation from which to further examine the relationship between language and mathematical abilities in children. In addition, the role of speech-language pathologists is expanding. It is imperative that the relationships identified in the present study regarding the assessment and remediation in both language and mathematics be considered by speech-language pathologists within the educational setting.

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Appendix A. Subject Recruitment Letter

Date

Name
Address

Dear Teacher:

I am a graduate student majoring in Communication Disorders and Sciences at Eastern Illinois University. In order to complete research necessary for my thesis, I am in need of normal fifth grade students who have not been diagnosed as language or learning disabled. I would appreciate your assistance in obtaining subjects for my study. Please distribute the enclosed parent letters discussing the study and permission forms to each child in your classroom. As children return their permission forms, I ask that you discard those from children that have been identified as language or learning disabled. I will collect the permission forms on _____.

Thank you for your time and cooperation.

Sincerely,

Heather Grant, B.A.

Appendix B. Parental Permission Form

Date

Dear Parent:

I am a graduate student at Eastern Illinois University majoring in Communication Disorders and Sciences. As part of my education in the field of speech-language pathology, I am conducting a study with fifth grade students. This study will involve measuring a student's ability to solve problems and use concept knowledge through scores obtained on two language tests and the mathematical portions of the Iowa Tests of Basic Skills. In addition, a hearing screening will be conducted. Participants must use English as a primary language. The testing session would take approximately 50-60 minutes and would be conducted at your child's school after school hours or at the Eastern Illinois University Speech-Language-Hearing Clinic on an evening or weekend.

Please consider allowing your child to participate in this study. Without the assistance and cooperation of parents, my study could not be conducted. Should you choose to allow your child to participate in this study, please sign and return the attached permission form to your child's classroom teacher by October 15, 1994. I will then contact you to arrange a testing date and time. In addition, if you prefer to provide the mathematical scores of your child's 1994 Iowa Tests of Basic Skills to me yourself, please return them with the permission form. If you have any questions or concerns, please feel free to contact me at the Speech-Language-Hearing Clinic (581-2712) or at my home (348-1545). Thank you for your time and assistance.

Sincerely,

Heather Grant, B.A.

Appendix B

I grant permission for my child, _____, _____,
 _____, to participate in the research
 _____, _____
 (name)
 (birthdate)
 study, "Investigation of the relationship between language
 and mathematics in regard to problem solving abilities."
 This study will be conducted by Heather Grant, graduate
 student in the Department of Communication Disorders and
 Sciences, Eastern Illinois University, Charleston, IL under
 the direction of Dr. Gail J. Richard.

I also (check one):
 _____ grant permission for Ms. Grant to obtain my
 child's mathematical scores of the 1994 Iowa Tests of
Basic Skills from their academic record at Jefferson
 Elementary School, Charleston, IL.

_____ agree to provide Ms. Grant with a copy of the
 mathematical scores of my child's 1994 Iowa Tests of
Basic Skills.

I understand that information in the study will be
 reported anonymously.

 Parent or Guardian

 Address

 Date

 City

 State

 Zip

 Phone (Day)

 (Evening)

Preferred testing time:

() after school

() weekend

() evening



Eastern
Illinois
University

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Appendix C. Research Approval from Human Resource

Office of Grants & Research
220 Old Main
Charleston, IL 61920-3099
(217) 581-2125

MEMORANDUM

TO: Gail Richard
Communication Disorders and Sciences

FROM: Bud May
Director of Grants and Research *Bud*

DATE: August 29, 1994

RE: Approval of Request for Human Subject Research

As per our earlier phone conversation, I am approving your request for human subject research involving a graduate thesis by Heather Grant under your direction.

Best wishes for a successful project.

ct