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ABSTRACT

A study investigated how elementary school students form a mental representation of simple addition and subtraction word problems, focusing on critical elements in the problems' semantic structure, and the extent to which the accuracy of the solutions found was related to the students' English language proficiency when the problems were presented in both Spanish and English. Subjects were 119 Mexican-American students in grades 2-5, divided into high (n=72 students) and low (n=47) English proficiency groups. Students were asked to solve 14 problems and answer 4-7 probe questions for each problem, designed to assess knowledge of information needed to solve the problems. Results show a main effect for grade level and language proficiency, and an interaction effect between grade level and proficiency. No difference was found between low and high proficiency students in accuracy of solutions, but low-proficiency students in higher grades performed less well on problems presented in both English and Spanish, contrary to expectation. Students who were able to answer comprehension questions generally got accurate solutions, although younger students had inadequate underlying semantic conceptual representation of the problem to find an accurate solution. Specific factors were associated with accurate comprehension. Problems and statistical results are appended. (Contains 27 references.) (MSE)

Comprehension and Solution Patterns of Simple Math Word Problems by Mexican-American, Bilingual, Elementary School Students

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Objectives and Theoretical Framework

The purpose of this study was to better understand how students form a mental representation of simple addition and subtraction math word problems via responses to several comprehension questions. The assumptions were based on information processing models proposed by Riley, Greeno, and Heller (1983); Carpenter and Moser (1982); Briars and Larkin (1984) and Kintsch and Greeno (1985) These researchers and others (Vergnaud, 1982; Nesher, 1982; Morales, Shute, & Pellegrino, 1985) contend that math word problem solving involves more than arithmetic computations. Processing the language to make sense of the underlying semantic relations in the word problem is also a critical component in math word problem solving. For Latino language minority students English language proficiency is an important factor to consider in assessing students' math word problem solving ability (Brenner, 1994; Spanos & Crandall, 1990; Baxter, Shavelson, Herman, Brown, & Valadez, 1992; Duran, 1988; Mestre, 1986; Cuevas, Mann, McClung, 1986).

The major purpose of this study was to use the critical elements assumed to be in the semantic structure of the math word problems (Riley, Greeno, and Heller 1983; Kintsch and Greeno, 1985; Briars and Larkin, 1984; Morales, Shute, and Pellegrino, 1985; Cummins, Kintsch, Reusser & Weimer, 1988; Hegarty, Mayer, & Green. 1992; Verschaffel, DeCorte & Pauwels, 1992; Cardelle-Elawar, 1992) and examine if, in fact, knowledge of this information was necessary in arriving at an accurate solution of the problems. This was done by examining the relationship between accuracy of the problem solution and responses to probe comprehension questions in three classes of math word problems. They were Change, Combine, and Compare math word problems.

A secondary purpose of the study was whether the accuracy of solution of word problems was related to the degree of English proficiency (High English or Low English) students had when the word problems were presented in both languages (Spanish/English).

Data Source

The study examined the solution and comprehension patterns used in solving 14 simple addition and subtraction math word problems by 119 Mexican-American/Mexican 2nd, 3rd, 4th, and 5th grade students. Seventy-two students were High LEP (Limited English Proficient) with intermediate English proficiency. Forty-seven were Low LEP (Limited English Proficient) with minimal to no English proficiency. Students were in a Late-Exit Bilingual Program. All students were still receiving instruction in the primary language (Spanish).

Method and Results

The study entailed presenting students with 4-7 probe comprehension questions for each of the 14 math word problems. An additional final question for each problem asked for the solution to the problem. Probe comprehension questions were intended to assess students' knowledge of information required to represent the Change, Combine, and Compare problems. The probe comprehension questions were administered to students in Spanish and in English.

A 3X2X2X2 ANOVA analysis examined 3 Grade Levels (2nd, 3rd, and 4th);two levels for Order of the Tests administered (A, Spanish/English and B, English/Spanish); two levels for Language of the Test (Spanish/English); and 2 levels for Language Proficiency (Low LEP/High LEP). Results showed that that there was a main effect for Grade Level ($F(2,93)=11.738$, $p < .001$ with mean scores of 4.258,6.355, and 7.015 for the 2nd, 3rd, and 4th grade respectively)

and Language Proficiency (Low LEP/High LEP, $F(1,93)=14.975$, $p < .001$, with means of 4.787 for Low LEP students and 7.389 for High LEP students).

There was also an interaction effect between Language Proficiency and Grade ($F(2,93)=3.644$, $p < .05$). The mean for 2nd grade Low LEP students was similar. It was 4.278 for Low LEP and 4.233 for High LEP students. The Low LEP 3rd grade had a mean of 5.050 while the High LEP had a higher mean of 7.806. The 4th grade Low LEP students had a score of 5.22 while the High LEP students had a score that was also higher (7.66.).

Additional ANOVA results showed no difference within the two language groups in accuracy of solution scores. However, significant differences were found between the two language groups. The High LEP students scored significantly higher in both languages, whereas the Low LEP students performed low in both the English and Spanish math word problem tests. This finding was unexpected and contrary to a previous study with monolingual Spanish speaking students (Morales, Shute & Pellegrino, 1985). The 2nd grade students performed the same in both languages. The difference in accuracy scores between language groups became evident only with the older students in the third and fourth grades.

Frequency scores, correlations and Chi-squares were used to analyze the probe comprehension questions According to the Chi-squares students who were able to answer the comprehension questions generally got accurate solutions. However,the solution and probe comprehension errors for the Compare problems indicated that some students can "appear" to understand the problem because they use the surface structure to represent the problem. More younger students (2nd graders) than older ones (4th and 5th) used the surface structure that resulted in incorrect solutions. These students did not have the appropriate underlying semantic conceptual representation of the problem to arrive at an accurate solution.

The following factors were found in this study to influence students' ability to comprehend and solve the math word problems accurately.

1. Coupling a quantity with a name in the word problem because it was in close proximity even if it did not result in a correct solution.

2. With Compare problems (CP4 and CP5) similarity of the surface structure to the underlying semantic structure of the problem resulted in incorrect solutions to the problem. Younger students (2nd) had more errors due to the use of the surface structure of the problem for solution. Older students (3rd, 4th) had less surface structure errors.

3. With the Change problems the more quantities that were associated with the same person's name, the greater the error of solution.

4. With the Combine problems difficulty differentiating between the superset quantity and the subset quantity produced greater errors of solution.

5. Performance due to language differences were evidenced with 3rd and 4th graders. Second graders showed no difference in accuracy scores between languages (Spanish/ English).

6. High LEP (Bilingual) students got similar high accuracy scores in both Spanish and English tests. However, Low LEP students got low accuracy scores in both tests.

Educational and Scientific Importance

Gagne, Yekovich and Yekovich (1993) explain that schema formation places a high demand on working memory because similarities of examples have to be noted and then encoded for conceptual representation. The language demands of using a language that Language Minority students do not command easily would be an added burden on the cognitive processing in formulating math word problem solving schemas. It is a fallacy that Language Minority students

will learn math concepts in a second language (English) because students will primarily be dealing with numbers (Cummins, 1986; Hakuta, Ferdman & Diaz,1987; Secada, 1992; Brenner, 1994).

As this study indicates students who have difficulty solving the problems also have a faulty conception of what the problem is about. Probe comprehension questions and discussion of the problem situation could be used to guide students in making the necessary inferences to understand the elements and relations in the problem. Students can be presented with a variety of problems sharing a similar underlying representation (schema). Using content that is familiar and relevant to students will heighten the motivation and enthusiasm needed to learn (Schoenfeld, 1991; Lucas, Henza & Donato, 1990).

Given the findings in this study as to how students are comprehending and attempting to solve these types of math word problems, instruction should be a comprehension-oriented process. Emphasis should be given to comprehending the story. Identifying the characters and the actions involved in the problem situation Instructional Standards set by the National Council for Teachers of Mathematics (1991) put an emphasis on worthwhile mathematical tasks; on the importance of active student participation; and effective forms of communication and discourse during mathematics instruction. The California Mathematics Framework (1990) states the following.

"Language is necessary to the learning of mathematics. It bridges new understanding with a student's previous knowledge and seals them. Students learn mathematics best in their primary language; therefore, they must be given the opportunity to do mathematics and create their own meaning by speaking." (p.45)

Based on the findings of this study it is recommended that a greater emphasis in instruction be placed on the comprehension component of math word problem solving. Comprehension of the critical elements in the word problem need to be clarified and students need

to have a conceptual understanding of the problem situation before attempts are made at deriving the solution. Otherwise, students randomly assign numbers and compute solutions to problems they don't thoroughly understand. This approach in understanding and solving math word problems provides students with a foundation for in-depth reasoning skills required for more advanced mathematical and scientific knowledge.

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DESIGN OF THE STUDY

Testing Order of Language		A (Span->Eng)	B (Eng->Span)
Grade	5th	High LEP (n=5)	High LEP (n=9)
	4th	High LEP (n=15)	High LEP (n=10)
		Low LEP (n=4)	Low LEP (n=5)
	3rd	High LEP (n=10)	High LEP (n=8)
		Low LEP (n=11)	Low LEP (n=9)
	2nd	High LEP (n=9)	High LEP (n=6)
		Low LEP (n=11)	Low LEP (n=7)
Total High LEP=72		High LEP (n=39)	High LEP (n=33)
Total Low LEP =47		Low LEP (n=26)	Low LEP (n=21)
Total N= 119		65	54

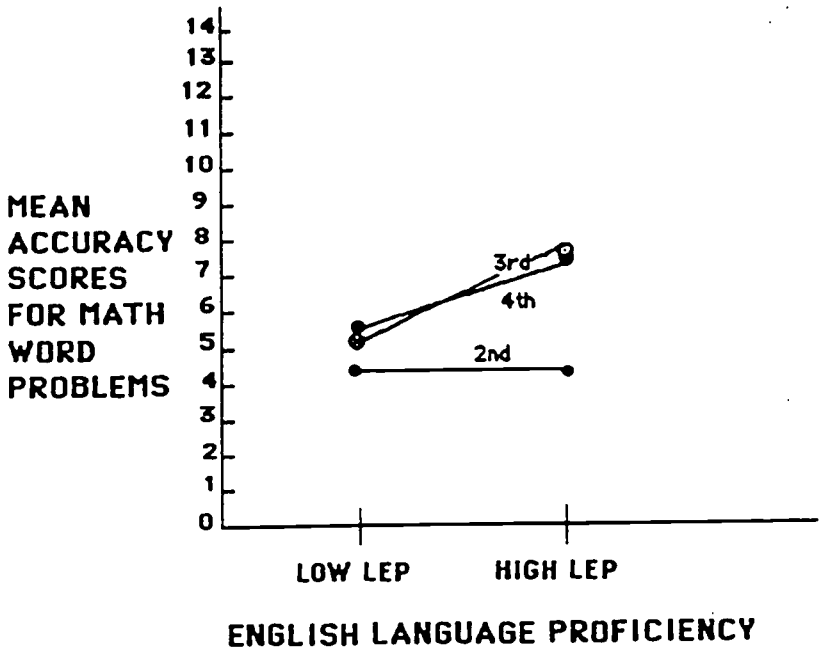

Figure 6. Interaction effects of grade by English language proficiency for Low LEP and High LEP 2nd, 3rd, and 4th grade students. (Combined English and Spanish scores)

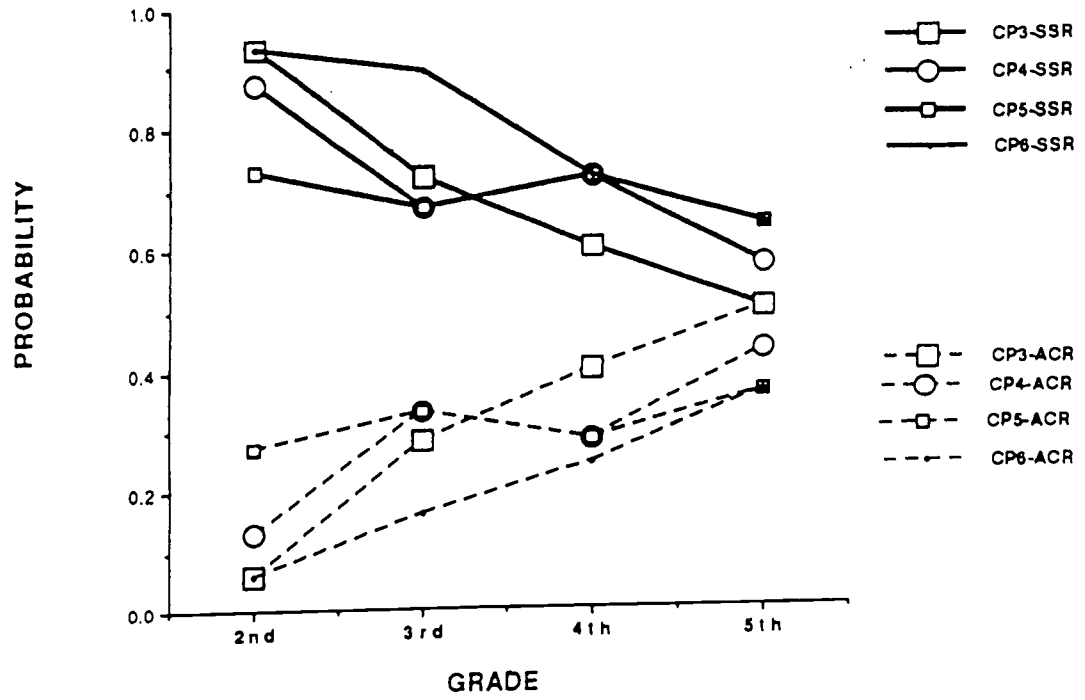

Figure 9. Age changes in usage of Appropriate Conceptual Reasoning (ACR) and Surface Structure Reasoning (SSR) strategies for representing Compare problems *CP3*, *CP4*, *CP5*, and *CP6*.

MOST FREQUENT TYPE OF SOLUTION ERRORS FOR CHANGE, COMBINE, AND COMPARE MATH WORD PROBLEMS

(CH)		
Change 1	Given Change Quantity .50	Subtract .40
Change 2	Given Change Quantity .28 Given Start Quantity .28	Add .33
Change 3	Given Start Quantity .45 Given Result Set .45	
Change 4	Given Result Set .88	
Change 5	Given Change Quantity .71	
Change 6	Given Change Quantity .50 Given Result Set .26	
(CB)		
Combine 2	Given Superset .61 Given Subset .27	
(CP)		
Compare 1	Given Larger Quantity .56	Add .26
Compare 2	Given Smaller Quantity .77	
Compare 3	More Than Difference .52 Given Larger Quantity .46	
Compare 4	Less Than Difference .85	
Compare 5	More Than Difference .77 Given Larger Quantity .13	
Compare 6	Less Than Difference .81	

N=72

SUGGESTED LESSONS FOR SIMPLE ADDITION AND SUBTRACTION MATH WORD PROBLEMS FOCUSING ON THE DIFFERENT SEMANTIC STRUCTURES OF THE MATH WORD PROBLEM

ROMELIA V. MORALES

DAY 1 CHANGE PROBLEMS

CH3, CH4

1. Display class store items with prices.
2. Make up problems with prices as in the class store.
3. Write one problem on the board and explain the action involved using the store items.
4. Students solve the problems and share their answers.

Use the following structure to make up 6 problems.

YOU HAVE_____.
YOU BUY SOME PENS.
NOW YOU HAVE_____.
HOW MUCH DID YOU SPEND ON THE PENS?

YOU HAVE_____.
THE TEACHER GIVES YOU SOME MORE PLAY MONEY.
NOW YOU HAVE_____.
HOW MUCH MONEY DID THE TEACHER GIVE YOU?

(Names and quantities can vary.)

5. Students buy items form the store after solving and sharing anwers.

DAY 2

CHANGE PROBLEMS
CH3, CH4

1. Display store items with prices.
2. Use same 6 problems as previous day.
3. Explain and simulate one problem.
   Focus on comprehension of the problem.
   Ask: Who is buying or giving?
   Who is getting?
   How much are they giving or buying?
4. Have 2 students come to where store items are displayed and simulate another problem.
5. Have students draw the action involved in each of the original 6 problems.
6. Students share drawings and describe to class.

DAY 3 CHANGE PROBLEMS

CH5, CH6

1. Display store items with prices.
2. Make up problems with prices as store items.
3. Write one problem on the board and explain using the store items.
4. Students solve and share their answers.

Use the following structure to make up 6 problems.

YOU HAVE A LOT OF MONEY.
YOU BUY A BOOK FOR _____.
YOU STILL HAVE_____ LEFT.
HOW MUCH DID YOU HAVE IN THE BEGINNING?

YOU HAVE SOME MONEY.
YOUR FRIEND GAVE YOU _____ MORE.
NOW YOU HAVE_____.
HOW **MUCH MONEY** DID YOU HAVE IN THE BEGINNING?

DAY 4 CHANGE PROBLEMS
CH5, CH6

1. Display store items with prices.
2. Use same problems as previous day.
3. Explain and simulate one problem.
   Focus on comprehension of the problem.
   Ask: Who is buying or giving?
   Who is getting?
   How much are they giving or buying?
4. Have 2 students come up and simulate a problem using the store items and play money.
5. Have students draw the action involved in each of the 6 problems.
6. Students share drawings and describe to class.

DAY 5 CHANGE PROBLEMS

CH3, CH4, CH5, CH6

1. Teacher explains structure of each problem.
2. Teacher makes up a problem for each structure.
3. Students make up own problems with the same structure. They can change the names and amounts. They make up 2 for each structure.
4. Students share problems and answers.

Use the sample structure from day 1 and day 3.

DAY 1 COMPARE PROBLEMS

CP1, CP2

1. Pass out store catalogues or newspapers with store items and proces.
2. Explain to students they are to find 2 items in in one store and look for those same items in another store.
3. Students will write :

item_____	item_____
store_____	store_____
price_____	price_____

4. Students will calculate the difference in the prices at the two stores. They will also answer the following questions.
   a. Where does it cost more?
   b. Where does it cost less?
   c. What is the difference in price?
5. Explain what difference is. "more expensive" "cheaper" "What you save" "What you need to have enough"

DAY 2 COMPARE PROBLEMS

CP1, CP2

1. Use same problems students made up from store catalogues.
2. Ask 3 students to share a problem they made up.
3. Teacher writes prices on the board in the following way.

item_____	item_____
store_____	store_____
price_____	price_____

   a. Where does it cost more?
   b. Where does it cost less?
   c. What is the difference?
4. Explain difference.
5. Students come to the board and share their problems. (6)
6. The rest of the class calculates the problem at their seats.

DAY 3

COMPARE PROBLEMS
CP3, CP4

1. Use items and prices students found in store catalogues.
2. Use the difference they calculated for each new problem.
3. Make up CP3 and CP4 problems by using the following structure.
4. Explain the new structure to students.
5. Students solve the problems and share their answers.

(something) COSTS _____ AT (some store).
(same thing COSTS (diff) MORE AT (other store)
HOW MUCH DOES IT COST AT (other store).

(something) COSTS _____ AT (some store).
(same thing) _____ COSTS (diff) LESS AT (other store)
HOW MUCH DOES IT COST AT (other store).

DAY 4 COMPARE PROBLEMS
CP3, CP4

1. Use same problems as day 3 .
2. Explain difference
   "more expensive" "cheaper" "what you save"
   "what you need to have enough"
3. Students draw items with prices from both stores.
4. Students share drawings and describe to class.

DAY 5 COMPARE PROBLEMS

CP5 CP6 "inconsistent language"

1. Display store items with prices.
2. Write a problem on the board with prices as store items.
3. Use items to explain problem.
4. Have 2 students use items to explain to class the problem.
5. Substitute numbers for original problems and make up 6 problems.
6. Students solve and share answers.

Example

A BOOK COSTS $15.
IT COSTS $10 LESS THAN THE YELLOW CAN.
HOW MUCH IS THE YELLOW CAN?

THE YELLOW CAN COSTS $25.
IT COSTS $20 MORE THAN THE MARKER.
HOW MUCH DOES THE MARKER COST?

Name Date

item_____	item_____
store_____	store_____
price_____	price

a. Where does it cost more?

b. Where does it cost less?

c. What is the difference?

item_____	item_____
store_____	store_____
price_____	price_____

a. Where does it cost more?

b. Where does it cost less?

c. What is the difference?

Explain difference.

	MAY CO.	MONTGOMERY WARD	(Difference)
Pintura Paint	14.95	5.49	_____
Lentes Glasses	25.00	4.95	_____
Aspiradora Vacuum Cleaner	145.99	59.96	_____
Televisión Television	255.95	129.00	_____

(Diferencia)

	(Difference)	THRIFTY	SEARS
Pintura/Paint		4.99	7.95
Lentes/Glasses		2.99	6.49
Aspiradora Vacuum Cleaner		39.95	89.95
Televisión Television		109.95	159.95

(Diferencia)

Write the prices at May Co.

	MAY CO.	MONTGOMERY WARD	(Difference)
Paint	14.95	5.49	9.46
Glasses	_____	4.95	20.05
Vacuum Cleaner	_____	59.96	86.03
Television	_____	129.00	126.95

Write the prices at Thrifty.

	THRIFTY	SEARS	(Difference)
Paint	4.99	7.95	2.96
Glasses		6.49	3.50
Vacuum Cleaner		89.95	50.00
Television		159.95	50.00

Explain difference.

	THRIFTY	SEARS	MAY CO.	MONTGOMERY WARD
Paint	4.99	7.95	14.95	5.49
Glasses	2.99	6.49	25.00	4.95
Vacuum Cleaner	39.95	89.95	145.99	59.96
Television	109.95	159.95	255.95	129.00

FIND 3 DIFFERENT ITEMS. COMPARE THE PRICES AND FIND THE DIFFERENCE.

¿Cuánto cuesta en la May Co.?

	MAY CO.	MONTGOMERY WARD	(Diferencia)
Pintura	14.95	5.49	9.46
Lentes	_____	4.95	20.05
Aspiradora	_____	59.96	86.03
Televisión	_____	129.00	126.95

¿Cuánto cuesta en la Thrifty?

	THRIFTY	SEARS	(Diferencia)
Pintura	4.99	7.95	2.96
Lentes	_____	6.49	3.50
Aspiradora	_____	89.95	50.00
Televisión	_____	159.95	50.00

Explica lo que quiere decir diferencia.

	THRIFTY	SEARS	MAY CO.	MONTGOMERY WARD
Pintura	4.99	7.95	14.95	5.49
Lentes	2.99	6.49	25.00	4.95
Aspiradora	39.95	89.95	145.99	59.96
Televisión	109.95	159.95	255.95	129.00

ESCOJE 3 ARTICULOS. COMPARA LOS PRECIOS Y CALCULA LA DIFERENCIA.

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