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The Development of a Math Strategy in Spanish for Latino English Language Learners at Risk for Math Disabilities

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Abstract

Math content for English Language Learners (ELLs) is unforgiving in terms of the constant need to build specific math and reading knowledge. As a result, ELLs may not only need math support but also reading comprehension support. The purpose of this study was to assess the effectiveness of a word problem solving strategy called Estratégica Dinámica de Matemáticas (EDM). EDM was designed to provide math strategy support in the native language based on students' reading and language comprehension levels. A changing criterion multiple baseline design was used to instruct six second-grade Latino ELLs at risk for math disability. As compared with the baseline phase, EDM increased word problem solving for all participants. All students' level of performance were maintained and generalized during follow-up sessions. This study has implications for a native language intervention that focuses on comprehension strategy training to facilitate word problem solving performance.

Keywords: English language learners, dynamic assessment, math comprehension strategies, single subject research design

In the American public education system (K-12), a large and growing number of students come from homes where English is their second language. These English language learners (ELLs) represent more than 5 million students, of which 75% are Spanish speaking (Planty et al., 2009). The challenges for many ELLs are not only overcoming a language barrier, but also achieving mathematically. Math achievement data indicate that ELLs are not performing at the same levels as their native English-speaking counterparts (National Center

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for Education Statistics, 2009). Rapid growth of the ELL population, as well as their low levels of math achievement and its consequences (e.g., high dropout rates, poor job rates, and poverty) create a vital need for improving instructional quality and enhancing student math outcomes.

The Problem

Word problem solving has its own developmental trajectory that is distinct from, but related to, reading comprehension (National Research Council, 2001). Although most ELLs develop sufficient number sense in school to perform word problem solving computations adequately, when reading word problems, many ELLs simply do not have the academic vocabulary and language skills to decipher the meaning of the sentences, and to apply this meaning to selecting suitable algorithms presented in word problems (Orosco, Swanson, O'Connor, & Lussier, 2013). As an example, the following word problem requires multiple comprehension skills for problem solving: "20 toy soldiers with helmets and 9 soldiers without helmets are for sale. The soldiers have green uniforms. How many soldiers are for sale?" Although a word problem like this is a math problem translated into words, every part of understanding a word problem is language and reading dependent (e.g., knowing that a mathematical operation can be signaled with a variety of terms, such as *how many*). Along the path of word problem understanding, an ELL needs to build and draw upon specific math terminology, math concepts, and reading comprehension skills. When ELLs carry out this cognitive processing, limitations in academic language and reading skills can lead to barriers in learning (Solano-Flores & Trumbull, 2003). Given the abstract and multistep nature of word problems, it is important that instructional models for ELLs provide a strategic approach not only in the English language but also in the student's native language in order to improve math solution accuracy.

Many of the comprehension strategies associated with the highest effect sizes for improving achievement of students at risk, directly and explicitly teach students strategies that prompt them to reflect before, during, and after word problem solving with instructional feedback (National Mathematics Advisory Panel (NMAP), 2008). These math strategies include: (a) methods of explicit and direct instruction that teach conceptual understanding of math concepts and principles of a word problem (e.g., Fuchs, Fuchs, Finelli, Courey, & Hamlette, 2004; Griffin & Jitendra, 2008; Jitendra, DiPipi, & Perron-Jones, 2002; Jitendra, Griffin, Deatline-Buchman, & Sczesniak, 2007; Orosco, Swanson, O'Connor, & Lussier, 2013; Swanson, Hoskyn, & Lee, 1999; Xin & Jitendra, 1999; Xin, Jitendra, & Deatline-Buchman, 2005), (b) visual representation techniques designed to bridge a connection from verbal information to symbolic understanding by creating a mental model (e.g., Jitendra & Xin, 1997; Jitendra et al., 1998; Jitendra et al., 2007; Van Garderen & Montague, 2003), (c) using instructional feedback with peer assisted learning strategies during instruction (e.g., Fuchs et al., 2008a; Fuchs, Fuchs, Yazdin, & Powell, 2002), and (d) small group instruction, instructional modeling, corrective feedback, and student verbalizations (Baker, Gersten, & Lee, 2002; Gersten et al., 2009; Swanson, 1999).

Although a great deal of evidence supports the value of teaching comprehension strategies (e.g., NMAP, 2008), much less is understood about how to adapt these instructional strategies for ELLs because much of the past research has focused solely on monolingual English-speaking students. In addition, the few math studies conducted with ELLs have not utilized their native language. ELL research continues to indicate that one of the strongest predictors of academic development is the use of the native language in instruction (Slavin & Cheung, 2005). Therefore, it may be critical that ELLs acquire math strategies in their native language, as the use of the home language may provide these students with the language comprehension skills necessary to understand first the math content they are reading, then to summarize key ideas, and finally to self-question while problem solving. Because of this, it is also important to learn which components of word problem-solving strategies are most effective for ELLs and how best to support them so that they can develop optimal strategy usage, especially when learning is mediated through the native language (García, Arias, Murri, & Serna, 2010).

Another challenge that arises from the math research is the high dependency on static measures (e.g., administered pre- and posttest), which assess a student's current problem-solving achievement by presenting scripted tasks that require the student to access previous learned knowledge with little teacher input (e.g., Grigorenko, 2009; Haywood & Lidz, 2007; Sternberg & Grigorenko, 2002; Swanson & Lussier, 2001). Because of this dependence on static measures, traditional assessment procedures have not been able to incorporate teacher-student interaction as part of the testing process nor measure to what degree feedback can help a student overcome problem-solving challenges. As a result of this, there is an opportunity in the math literature to develop an assessment model that can be used to identify word-problem solving challenges, make diagnostic decisions, and propose instructional strategies that address learning challenges to ELL students. The purpose of this study was to assess the effectiveness of such a math comprehension strategy procedure based on a dynamic assessment (DA) framework with ELL students.

In traditional static models of assessment and instruction, the student's current competencies are measured, and the assessor does not intervene so as not to "influence" the results (Haywood & Lidz, 2007; Sternberg & Grigorenko, 2002). In contrast, DA models both assess the student's current state of competency and determine whether substantive changes can occur in student performance due to instructional scaffolding across an array of increasingly more challenging tasks, in order to determine the student's immediate potential for learning. During DA, a teacher facilitates a student's ability to build on prior knowledge through student-teacher interaction, and uses this mediation process as a way to help the student internalize new information (Vygtosky, 1978). A standardized protocol is used to measure the distance, the difference between, and/or change from unassisted performance to a performance level with assistance (i.e., Zone of Proximal Development, ZPD; Sternberg & Grigorenko, 2002). One of the major strengths of DA is that it provides a clear link between assessment and teaching because it can incorporate a student's response to instructional feedback (Swanson & Orosco, 2011). Thus, the benefit of using a DA measure of assessment on a math comprehension strategy framework is that it not only provides more information about the learning processes of the student but it also allows for a more fluid development of a strategy measure through ongoing refinement, while the contextual relevance helps to establish a strategy assessment's validity (Shephard, 2000).

Although the DA literature is vast, the empirical validity of dynamic assessment with regard to math is sparse (e.g., Fuchs et al., 2008b; Seethaler, Fuchs, Fuchs, & Compton, 2012), particularly regarding assessments with Latino ELLs at risk for math disabilities (MD) (e.g., Orosco, Swanson, O'Connor, & Lussier, 2013). While the literature is clear that word problem solving limitations in ELLs are related to academic language and reading performance, whether DA procedures in the native language add additional information to the prediction of growth in math in ELLs at risk for MD beyond traditional testing procedures has not been tested. In addition, because of the individualized nature of DA, the literature has not typically reported the reliability and validity in treatment-oriented studies (Caffrey, Fuchs, & Fuchs, 2008). Alternatively, more research-oriented DA methods, such as graduated prompts, have been found to be more efficient and standardized for research and practice (Haywood & Lidz, 2007). The purpose of this study was to investigate a dynamic assessment math strategy called Estratégica Dinámica de Matemáticas (EDM) based on a graduated prompt framework that was developed in the participants' native language (Spanish). EDM was operationally defined in this study as the interventionist modifying math language via a four-level math vocabulary modification procedure (see Table 1) to the students' level of math comprehension, and then providing strategy instruction feedback by means of verbal probes that assessed students' level of word problem solving ability in their native language. This study addressed two research questions with Latino ELLs:

1) To what extent does EDM facilitate a student's word problem solving accuracy when compared to the baseline conditions?
2) To what extent does EDM maintain word problem solving skills accuracy in follow-up sessions?

Method

Setting and Participants

Six second-grade Latino ELLs at risk for math disability from a southern California dual language (English/Spanish) elementary school classroom participated in this study. For the purposes of this study, Latino English language learners (Latino ELLs) was defined as those students who speak Spanish as their native language 100% of the time at home, are identified as coming from Latin American descendants (e.g., Mexican, Mexican-American), are in the process of acquiring English as a second language, and who have not achieved full English proficiency (California English Language Development Test, CELDT; Marr, Rodden, & Woods, 2009). The school's population consisted of 453 students (55% Hispanic (all Latino ELLs), 22% African Americans, 14% White, 5% Asian, and 4% other).

Table 1.

Los Afectos de la Estratégica Dinámica de Matemáticas Resolviendo Problemas de Palabras en los Estudiantes que están Aprendiendo Inglés como Segundo Idioma

Nivel de Modificación Lingüística (Linguistic Modification Level)	Descripcion (Description)	Ejemplo (Example)
Principiente (Nivel 1) (Basic (Level 1))	Terminos de matemáticas utilizados en conversaciones diarias (Math terms used in everyday conversation)	antes (before), después (after), combinar (combine), extra (extra) junto (together), más (more), más que (greater than), en total (total), menos (fewer), surtir (sort), menos que (fewer than), quitar (take away)
Intermedio (Nivel 2) (Intermediate (Level 2))	Términos no directamente asociados con un específico contenido de la área de matemáticas (Math terms not directly associated with a specific math content area)	adición (addition), agregan (sum), dígitos (digits), division (division), multiplicación (multiplication), factor (factor), factores (factors), resta (subtraction)
Avance Intermedio (Nivel 3) (Advance Intermediate (Level 1))	Términos de matemáticas directamente asociados con un específico contenido de la área de matemáticas (Math terms directly associated with a specific content area)	cociente (quotient), divisor (divisor), divisible por (divisible by), dividend (dividend), mínimo común denominador (least common denomimator), mínimo común múltiplo (least common multiple)
Vocabulario Técnico (Nivel 4) (Technical Vocabulary (Level 4))	Términos de matemáticas asociados con un específico contenido del tema de la area (Math terms associated with a specific math content area topic)	perímetro (perimeter), area (area), cilindro (cylinder), pulgada (inch), metro (meter), centímetro (centimeter), milla (mile), rectángulo (rectangle), cuadrado (square), triángulo (triangle), cubo (cube), triángulo recto (right triangle)

Note. Adapted from G. Ernst-Slavit & D. Slavit (2007); Orosco, Swanson, O'Connor, & Lussier (2013)

The majority of participants were from reduced socio-economic backgrounds based on school district reporting of 75% of the school's student population participating in the free or reduced-price lunch program.

This study was conducted as a pullout program during school hours for 17 sessions (average 20-25 min per session) over a five-week period and was a supplementary curriculum intervention to the general education math curriculum (*California Houghton Mifflin Matemáticas Grade 2,* Houghton Mifflin Company, 2002) that students received as part of their regular school day (50 minutes per day). The curriculum used in this study was part of the school's math program of developing new teaching techniques, interventions, and strategies that promoted students' oral language development (e.g., vocabulary development) by building their background knowledge (e.g., modifying the linguistic complexity of math language and rephrasing math problems, and building knowledge from real world examples) within a standards-based math education (National Research Council, 2001). Participant selection criteria (see Table 2) included: (a) a school district home language survey that indicated the student's dominant language spoken at home was Spanish; (b) scoring below grade level on district reading and math assessments; (c) the California English Language Development Test (CELDT; Marr, Rodden, & Woods, 2009) to define ELL status; (d) the Batería III Woodcock-Muñoz: Pruebas de Aprovechamiento, Prueba 10: Problemas Aplicados (students who performed in the lower 25th percentile were included in the at-risk sample; Fletcher et al., 1989); (e) teacher recommendation for Spanish intervention based on students previously experiencing word problem solving challenges and having been designated at risk for math disability; and (f) parent consent. The CELDT is a measure of English proficiency (listening, speaking, reading, and writing) with reliability scores between .73 and .94 across grade levels (Marr et al., 2009).

Students' word problem solving skills were measured with the *Batería III Woodcock-Muñoz: Pruebas de Aprovechamiento, Prueba 10: Problemas Aplicados* (Muñoz-Sandoval, Woodcock, McGrew, & Mather, 2005). This subtest measures the ability to analyze and solve math problems. This test has a mean standard score of 100 and a standard deviation of 15. The *Batería III* was calibrated both inside and outside the United States (Spanish-speaking world). The *Batería III* was standardized on a stratified normative sample of 1,692 native Spanish-speaking participants and has a reported internal reliability coefficient of 0.95 for *Prueba 10* age 9 (Woodcock, McGrew, & Mather, 2007). The same test was also administered at post assessment. Pre- and posttest data were compared with multiple baseline data, in determining whether EDM positively mediated learners' word problem–solving skills (i.e., math comprehension) over time. Table 2 provides descriptive, school-related information and *Batería III: Prueba* 10 data.

Table 2
Demographic, School-Related Data, and Prueba 10 Pre and Post Test Scores

Student	Gender	Age	District Reading Assessment Level	District Math Assessment Level	Prueba 10 Pretest Percentile (%)	Prueba 10 Pretest Standard Score	Prueba 10 Posttest Percentile (%)	Prueba 10 Posttest Standard Score
Alma	Female	7.7	1.5	Below basic	18	86	21	88
Lissette	Female	8.1	1.7	Below basic	19	87	22	89
Miles	Male	8.2	1.6	Below basic	19	87	22	89
Blanca	Female	8.1	1.8	Below basic	20	88	21	88
Daniel	Male	8.2	2.0	Below basic	20	88	23	89
Vincent	Male	7.7	1.9	Below basic	20	88	23	89
M		8.0	1.75		19.33	87.30	22.00	88.83
SD		.22	.17		.82	.82	.89	.41

Note: Prueba 10 = Batería III Woodcock-Muñoz: Pruebas de aprovechamiento, Prueba 10: Problemas aplicados

Intervention

The EDM intervention was designed on a reciprocal teaching foundation (Palinscar & Brown, 1984) and the features associated with effective math instruction (e.g., collaborative group work, interactive dialogue, procedural strategies; e.g., Baker, Gersten, & Lee, 2002; Gersten et al., 2009; NMAP, 2008; NRC, 2001). EDM was implemented in two phases: (a) teaching the strategies, and (b) collaborative learning group activity or student pairing. Students were first pretaught specific math concepts, ideas, vocabulary and terminology in Spanish for each lesson by elaborate teacher modeling. As students came to understand the information presented, the teacher then began to integrate and embed probes and strategy instruction with collaborative learning.

Phase 1: Teaching the strategies. Students learned five word problem-solving strategies: *Saberlo-Qué se de la pregunta* (Know it-What do I know about the question), *Buscarlo-Necesito encuentrar el vocabulario y los numeros importantes* (Find it-I need to find the important vocabulary and numbers), *Muestralo* (Set it up), *Resolverlo* (Solve it), and *Comprobarlo* (Check it).

1. *Saberlo*. *Saberlo* is a strategy to activate students' prior knowledge, to facilitate their predictions about what is already known about the problem. The strategy consists of two activities: (a) brainstorming about the problem and (b) making predictions on how the problem may be solved. The teacher introduces the word problem (which has been read aloud) by asking them to think about the word problem and to then find the question. In this step, the teacher prompts the students to tell (a) what they know about the question and (b) what they think they will learn from the problem.
2. *Buscarlo*. *Buscarlo* teaches students to find critical information for meaning and understanding to solve the problem, and teaches them how to use strategies to help

them figure out unknown words or concepts.

3. *Muestralo*. *Muestralo* helps students begin to set up problem solving during reading by stopping after each sentence to find the main idea and to check to see if this information is relevant to solving the problem. Students are taught to identify the main concept of a sentence by answering the following questions: (a) What is this sentence about? and (b) Is this information needed to solve the problem? In addition, students are taught to write this information down, so that they can begin to use it to solve the problem.
4. *Resolverlo*. The *resolverlo* strategy takes the information that has been gathered and writes it into a number sentence that tells about the problem. The teacher and students then discuss it and set to work to solve the problem. Students check their understanding by generating and answering questions about what they have read and reviewing what they have learned by summarizing the key ideas presented in the word problem, solving it, and checking it.
5. *Comprobarlo*. The *comprobarlo* strategy focuses on presenting students with standard algorithms to solve the problem, explain how and why they work, and offers them as one way to solve a problem. In addition, during this strategy, it is important for students to understand that there are multiple ways, including the ones they may have invented, to solve a problem correctly.

Phase 2: Cooperative learning and/or student pairing. Once students were proficient in strategy usage, they were provided a collaborative approach between the teacher and student that allowed the students to practice this method. In this stage, the student was assigned the leadership role and imitated the teacher's role. Within this process, the student generated and asked questions to check for understanding. The student then solved the problem and checked to see if it was answered correctly. If answered incorrectly, the problem-solving process was repeated between the teacher and student again, to see where mistakes were made. As they reviewed, the teacher monitored the student's effectiveness by providing probes as needed (e.g., reading words, clarifying math concepts, or reminding students of a strategy skipped). If word problem solving challenges persisted, the teacher then retaught specific strategies by means of reciprocal teaching (Palinscar & Brown, 1984) until the student understood them.

Experimental Design

A changing criterion multiple baseline design across subjects (Horner et al., 2005; Kazdin, 2010; Kratochwill et al., 2010) was used to evaluate the effects of the EDM intervention strategy. In this design, each intervention session is associated with a stepwise criterion rate for the target behavior (i.e., word problem solving level of difficulty was advanced after a student solved a set of word problems correctly). Participants were selected and categorized based on teacher recommendation (i.e., low math and reading scores in Spanish), and the amount of intervention needed, and from this, a list was generated that rank ordered students based on the amount of intervention needed. After students' solution accuracy was stable in the baseline phase (see baseline section for description), the independent variable was introduced and maintained across subjects until the minimum number of sessions necessary to establish criterion response stability (minimum of three sessions above the baseline mean) was achieved. All participants were individually administered four word problems per intervention session similar to those used during the baseline phase.

Word problems. All word problems were matched to those used in daily instruction. However, word problem presentations were modified to capture four levels of language difficulty: conversational, non-associated content, associated content, and technical vocabulary. During each session, four word problems per level were administered. These word problems were linguistically modified based on a scaffolding ladder that parsed the language of mathematics into four levels, with each level providing scaffolding that supported the next higher level of word problem solving development. Level 1 word problems were embedded in math terms used in every conversation (high frequency words), Level 2 word problems incorporated math terms not directly associated with a specific math content (general math words), Level 3 word problems incorporated math terms directly associated with a specific math content area (specialized math vocabulary), and Level 4 incorporated math terms associated with a specific math content area topic (technical vocabulary). As an example of this scaffolding, a Level 2 word problem may have asked, Juan tiene 24 monedas que agregan 27¢. ¿Qué monedas tiene? (Juan has 24 coins worth a sum of 27¢. What coins does he have?). In this case, the word problem was made less linguistically complex by taking the Level 2 math term (agregan, sum), and teaching a level one meaning (total) without altering the math concept being taught.

Probing. In this study, a probing procedure was developed in Spanish by the researcher (Appendix A), in which the dependent variable was the word problem language level (i.e., the administration of four word problems per level with the algorithm for solution constant across all levels) achieved with the strategy intervention. The probe was designed to recompose differing levels of word problem-solving skills through the application of five prompts (scaffolds) in determining the student's word problem achievement with and without scaffolding. Scoring of the five prompts involved the assignment of points at each prompt (0 = incorrect response, 1 = correct response). As part of the probing procedure, each student was asked to solve four word problems at their zone of proximal development language level. After a 3-minute duration, if the student was having difficulty solving the problem, the student was given the prompts with 1 minute to answer each prompt. Another prompt (with a maximum of five) was initiated if the student failed to respond correctly to the previous one. The administration of prompts averaged 4 to 5 minutes in duration. The number of prompts administered to solve the problem was used to establish the student's level of intervention needed to solve word problems accurately.

Procedure

Baseline phase. At the baseline, each participant was individually administered math problems in Spanish that contained four progressive language levels of word problem solving difficulty. The word problems included addition, subtraction, multiplication, and division. Students were instructed to do their best, and given as much time as needed to solve the problems. None of the participants required more than 10 minutes in attempting to solve the problems. This established the baseline score for each participant. The baseline determined the language level at which word problems could be accurately solved without assistance. This also established the starting level for the intervention curriculum. Five of the six participants (Alma, Lissette, Miles, Blanca, and Daniel – all aliases) started at word problem solving Level 1. Vincent (also an alias) established a Level 2 baseline.

Intervention phase. A bilingual trained classroom teacher and the researcher alternated sessions in applying the intervention. Both the research and teacher had received training at the graduate level in ESL/Bilingual reading and math pedagogy, and the teacher was trained on how to use the intervention. The word problem solving intervention was delivered individually, and consisted of three steps: (a) preteaching math concepts and vocabulary, (b) strategy instruction that integrated math concepts and vocabulary, and (c) up to 5 probes to improve word-problem solving performance. Each instructional session lasted an average of 25 minutes. After each session, students were administered a set of four math word problems based on their current language level to solve without probes or any other form of assistance. Each student was required to correctly solve these problems at their unassisted level (demonstrating 100% mastery) in order to progress to the next level.

Preteaching concepts and vocabulary (step 1). At this step, the student was provided with direct and explicit instruction of key concepts and vocabulary from math word problems that they were asked to solve for the session. The student was provided with a series of 3- x 5-inch index cards that had a vocabulary word written on one side and was blank on the other side. The intervention teacher modeled the activity by holding up the card, looking at the word, pronouncing the word (asking the student to repeat the word), providing various meanings of the word through contextualization (e.g., everyday language), writing these on a vocabulary chart, and then applying them to a math problem. On the blank side of the card students were asked to write a student friendly definition of the word and write a math example (so that they could practice these words at home). The researcher stated (see Appendix B for English vocabulary translation), Esta es la palabra *sumar (suma)*. La palabra *sumar* puede significar *mas, anadir, o combinar* con el signo (+). (On the chart board the interventionist wrote +, *mas, contar, poner, combinar*. Next, the interventionist contextualized this vocabulary, "Julio fue al mercado y compró 5 paquetes de piedritas rojas y 5 paquetes de piedritas azules para poner en la pecera. ¿Cual es la suma de todos los productos? ¿Qué significa la palabra *suma* (writing *suma* on the chart board)? *Suma* significa *combinar* (+). ¿Cual es la suma de todos los productos? Cinco paquetes de piedritas rojas y cinco paquetes de piedritas azules son diez. Interventionist, "Ahora me puedes dar un ejemplo. Student, “Yo fui a la tienda y compró 3 paquetes de piedritas rojas y 3 paquetes de piedritas azules. ¿Cual es la suma? Suma significa combinar. Tres mas tres seis paquetes de piedritas (3 + 3 = 6). ¡Muy bien!"

If the student encountered challenges in providing an example, the interventionist prompted the student with other contextualized examples, until the student understood. This was repeated three times with all the vocabulary covered for that session.

Comprehension strategies instruction (step 2). During each intervention session, the teacher/researcher modeled the problem solving process by applying strategies using a cue sheet (see Appendix C for Spanish example and Appendix D for English translation) developed for the study. In this step, this strategy asked the student to consider her/his background knowledge on the word problem they were reading; in addition, the student was asked to identify the problem by determining the question and identifying vocabulary. If the student struggled with the task, the teacher provided further support via probing. The instructor also provided systematic and ongoing feedback that sought to build upon preteaching strategies. Next, the teacher and student collaborated in finding the key data to set up the problem, and then to calculate and solve the problem. The teacher then noted whether the problem had been solved correctly and directed the student to generate questions so she/he could determine whether the student comprehended the problem. Asking the student to evaluate what she or he had learned by summarizing the key concepts presented in the word problem did this.

Dynamic assessment (step 3). The DA step of the intervention involved the participants being assessed using probes (Appendix A) to assess word problem-solving accuracy. The student was administered a set of four word problems with the math vocabulary and concepts reviewed during intervention. This duration of this administration averaged 10 minutes. If the student answered the problem independently (correctly without probes), the student was given a total score of 5 (correct response) and moved to the next level in the following intervention session. If the student was not able to answer the question correctly, she/he was given a score of 0 for that problem and then given the probes in sequence. If the student answered the problem with the first probe's assistance correctly, she/he was then scored a 1 on probes needed and moved on to the next problem. If the student was unable to answer the problem correctly with the first probe, the student was given additional probes (a maximum of 5) at the current level with the number of probes needed being recorded. Students changed levels when the criterion of 100% was achieved at their current level.

Social Validity

At the conclusion of the study, the social validity of the intervention was assessed using a three-question interview protocol. During this interview, the participants were asked questions in Spanish regarding their satisfaction with EDM (e.g., ¿Crees que EDM te ayudó a comprender los problemas de palabras? Explique por favor. Do you think that EDM helped you to understand word problems? Please explain.).

Interobserver Agreement and Treatment Integrity

In order to check on the degree to which intervention techniques were being applied in teacher interactions with students, a treatment integrity checklist based on the sequence of probe statements (e.g., pacing, quality of instruction, and scaffolding) for each intervention was applied. The checklist was completed at the beginning (two sessions), middle (two sessions), and end (two sessions) of the intervention phase by an observer. The observer would code for fidelity via a checklist and score "yes" or "no" for each probe observed. A total agreement calculation method for each session (i.e., dividing the number of agreements between the probe responses by the number of disagreements and then multiplying by 100) indicated the consistent presence of intervention behaviors being used at 100%. Interobserver agreement for all four levels was 90% at baseline, and 100% at intervention and maintenance phases. The dependent measure across all training sessions was the "language level" of proficiency without assistance. To progress through the levels of criterion performance, each student was required to solve four consecutive word problems at their unassisted level (100% mastery).

Results

Figure 1 displays the language level criterion for word problems for each participant as a function of baseline, intervention, and maintenance sessions. Visual analysis showed increases in word problem solving accuracy as a function of language difficulty. During each session, students were administered a set of four word problems starting at Level 1. Table 3 lists the number of word problems solved correctly and incorrectly, with an accuracy percentage score (APS) based on the administration of these problems per session. An asterisk (*) denotes the student's move to the next criterion level. Also shown are Batería III Prueba 10 pre–posttest gains (Table 2).

Baseline Performance

The student named Alma received a total of three baseline sessions, and her mean APS was 50%. Next, Lissette was administered four baselines, and her mean APS was 44%. Miles was given five baselines, and his mean APS was 65%. Blanca was administered six baselines, and her mean APS was 63%. Daniel was administered seven baselines, and his mean APS was 71%. Finally, Vincent was administered eight baselines, and his mean APS was 63%. Although the participants' performance on word problem solving was stable, when these scores were broken down into language level (4 problems correct without help), five of the six participants (Alma, Lissette, Miles, Blanca, and Daniel) started at a baseline Level 1. Vincent established a Level 2 intervention phase, as a result of higher reading and math

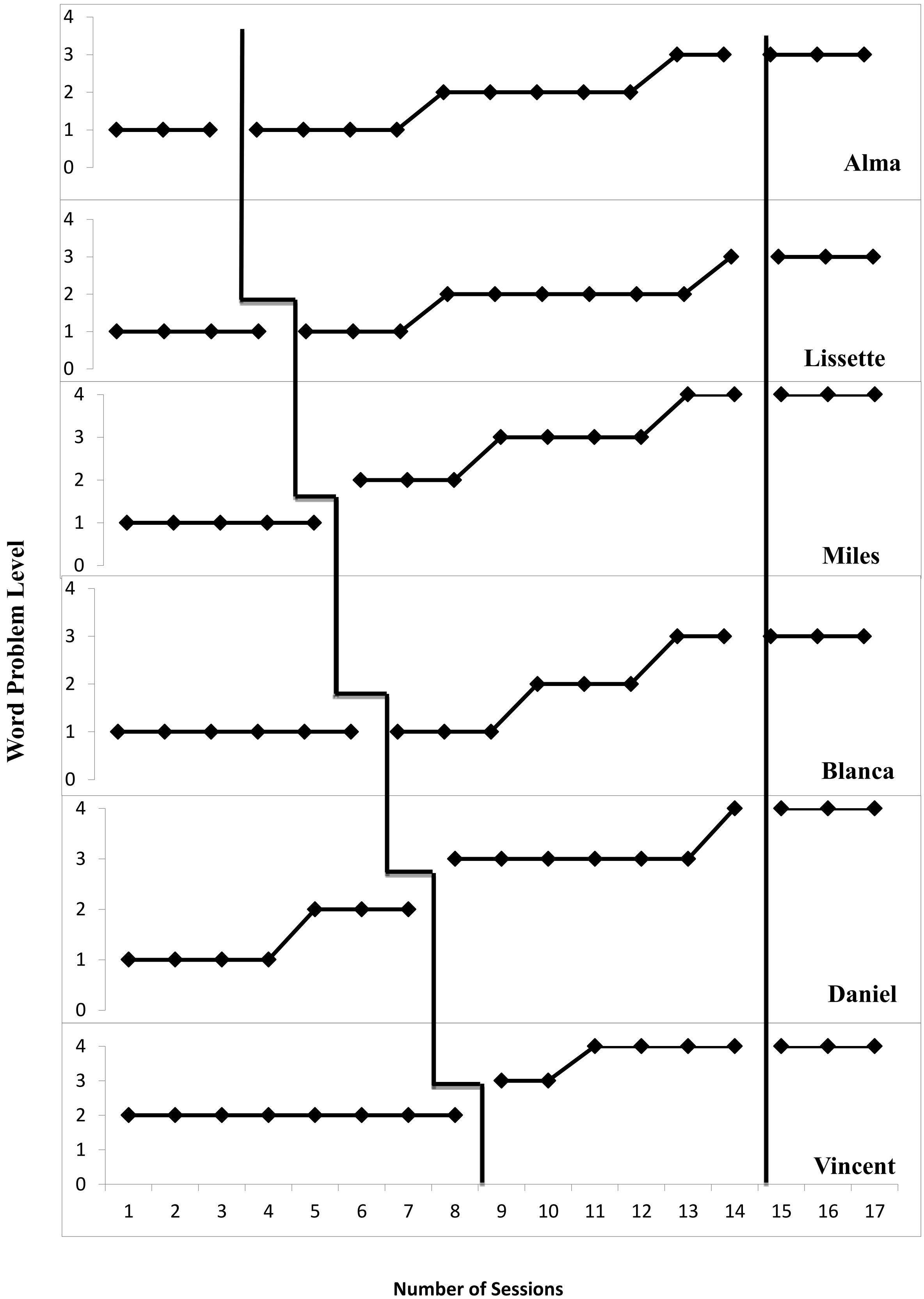

Figure 1. **Word problem level achieved**

Table 3

Word Problems Solved Correctly and Incorrectly per Student Session

	Alma							Lissette							Miles						
Session	B		I		M		APS	B		I		M		APS	B		I		M		APS
	IC	C	IC	C	IC	C	%	IC	C	IC	C	IC	C	%	IC	C	IC	C	IC	C	%
1	2	2					50	3	1					25	2	2					50
2	2	2					50	2	2					50	1	3					75
3	2	2					50	2	2					50	1	3					75
4			2	2			50	2	2					50	2	2					50
5			1	3			75			2	2			50	1	3					75
6			1	3			75			2	2			50			*1	3			75
7			0	4			100			0	4			100			1	3			75
8			*1	3			75			*2	2			50			0	4			100
9			2	2			50			0	4			100			*1	3			75
10			1	3			75			1	3			75			1	3			75
11			1	3			75			3	1			25			1	3			75
12			0	4			100			1	3			75			0	4			100
13			*1	3			75			0	4			100			*2	2			50
14			0	4			100			*1	3			75			1	3			75
15					0	4	100					0	4	100					0	4	100
16					0	4	100					1	3	75					0	4	100
17					0	4	100					0	4	100					1	3	75

	Blanca							Daniel							Vincent						
Session	B		I		M		APS	B		I		M		APS	B		I		M		APS
	IC	C	IC	C	IC	C	%	IC	C	IC	C	IC	C	%	IC	C	IC	C	IC	C	%
1	2	2					50	2	2					50	2	2					50
2	2	2					50	1	3					75	2	2					50
3	1	3					75	1	3					75	1	3					75
4	2	2					50	0	4					100	1	3					75
5	1	3					75	*1	2					50	2	2					50
6	1	3					75	0	4					75	1	3					75
7			1	3			75	0	4					75	1	3					75
8			0	4			100			1	3			75	2	2					50
9			0	4			100			1	3			75			1	3			75
10			*1	3			75			1	3			75			0	4			100
11			2	2			50			0	4			100			*2	2			50
12			0	4			100			*1	3			75			0	4			100
13			*1	3			75			0	4			100			2	2			50
14			1	3			75			*1	3			75			1	3			75
15					0	4	100					1	3	75					1	3	75
16					1	3	75					0	4	100					1	3	75
17					0	4	100					0	4	100					1	3	75

Note. B = baseline phase; I = intervention phase; M = maintenance phase; APS (%) = accuracy percentage score; IC = incorrect; C = correct; * = start of next level.

achievement scores in the native language. However, the low performance on more language complex and difficult word problems for all the participants at the baseline phase indicated a need for further intervention. Pretest scores on the Batería III Prueba 10 also indicated a need for further mediation.

Intervention

As compared with baseline scores, the intervention condition administered in the students' native language produced an increase in both accuracy and level of word problem difficulty solved while the treatment was in effect. After each intervention session, each participant was administered a set of four word problems based on the intervention language level received. Students' word problem solving accuracy during this phase is presented in Table 3, and word problem level achieved is shown in Figure 1.

Alma received 11 intervention sessions, her mean APS on word problem sets was 77%, and she demonstrated a gradual increase in word problem level performance (i.e., from Level 1 to Level 3) from baseline level. Lissette received 10 treatment sessions, her mean APS on word problem sets was 70%, and she also showed an increase in word problem level from Level 1 to Level 3. Similarly, Miles, received 9 intervention sessions with a mean APS of 78%, and obtained a word problem Level 4. Blanca received 8 intervention sessions; her 81% mean APS showed a gradual increase from level 1 to level 3. Finally, Vincent received 6 intervention sessions, and his mean APS was 75%.

In summary, all students benefited from intervention with increases in accuracy percentage scores after students were directly and explicitly taught math concepts and vocabulary that connected to everyday words.

Maintenance

To determine maintenance of intervention skills, all students were individually administered four math word problems similar to those used during the preassessment phase for three sessions. During this phase, all students sustained word problem solving accuracy (see Table 3) and word problem levels achieved (see Figure 1) similar to the end of their intervention phases. Examination of the outcomes shows that Alma maintained the highest level of performance (100% at Level 3), while, Lissette, Blanca, and Daniel maintained a mean APS of 92% at Level 3, and Miles a mean APS of 92% at level 4. Finally, Vincent's mean APS remained stable at 75% (Level 4).

In summary, during the maintenance phase, visual inspection of the data on students' word problem solving accuracy and word problem difficulty level achieved indicates that they were able to maintain a higher level of performance due to EDM treatment. Posttest scores on the Batería III Prueba 10 also indicated that students showed improvement from the intervention.

Social Validity

Qualitative interview data indicate that the majority of the participants were in agreement (83%) that the intervention procedures were reasonable and effective. Several students commented around the theme “Me gustó mucho la enseñaza de matemáticas, nosotros podríamos hablar. (I like the teaching, we could talk).” Only one student, Vincent, said he did not like it because “Fue muy lento. (It goes too slow).” The homeroom teacher commented, “La intervención es bastante sencilla enfoque que permite integrar el vocabulario y la comprensión de estrategias de la lectura con la instrucción de matemáticas. (I really liked the simplicity of the strategy, and how easily it integrated vocabulary and reading comprehension strategies with math instruction.” The students recommended “mas juegos de matemáticas (more math games),” while the teacher would have liked more writing in Spanish for each student to help them solidify their word problem solving literacy: "Un diario de matemáticas para cada uno de los estudiante que le podrían ayudar a solidificar sus conocimientos de matemáticas por medio de la escritura. (A math diary for each student that would help them reflect on their own math learning through the medium of writing.)"

Discussion

The purpose of this study was to investigate the effects of a math intervention in Spanish, called Estrategia Dinámica de Matemáticas (EDM), on Latino ELLs’ word problem solving achievement. This study addressed the following two questions:

1) To what extent does EDM facilitate student’s word problem solving accuracy when compared to the baseline conditions?

The results of visual analysis and examination of graphed accuracy percentage scores supported the hypothesis that EDM facilitates an improvement in word problem solving accuracy from baseline conditions. The results indicated a functional relationship between EDM and increased word problem solving performance because the intervention was able to provide scaffolding instruction that positively mediate word problem skills and language over time, It gave instructional feedback based on students’ current performance levels (known) and students’ assisted performance (potential) levels. Posttest scores on the Batería III Prueba 10 also confirmed this improvement. In summary, as students’ knowledge of EDM increased, their ability to accurately solve increasingly complex word problems improved during intervention in comparison with the baseline phase.

2) To what extent does EDM maintain word problem solving skills’ accuracy in follow-up sessions?

The follow-up results of EDM indicated that students were able to maintain knowledge of the EDM process during three follow-up sessions after intervention and relevant to the baseline phase. All subjects demonstrated generalization of the DA strategy to more complex verbal math problems by maintaining their word problem solving performance at the intervention level. Overall, the results indicate support for the two questions that motivated this pilot study.

The findings from this study lend support to the current literature in this area in three key areas. First, dynamic assessment (DA) theory suggests that scaffolding instruction can positively mediate math comprehension over time because it can give performance-contingent feedback based on students' independent performance (known) and students' assisted performance (potential) that promotes cognition. The EDM results demonstrated this mediation during intervention. Although students in this project had the number sense and calculation skills to perform word problem solving computations adequately, when facing word problems, they needed assistance with understanding the math vocabulary and reading comprehension tasks in order to decipher the meaning of the sentences, and to apply this meaning to selecting suitable algorithms in order to solve word problems. These findings are consistent with DA theory and provide further evidence that DA may be an effective framework for improving word problem solving skills in ELL students.

Second, the findings of this study provide additional support for reading comprehension strategies instruction (CSI) as an effective method for teaching ELLs math problem solving skills. Results from the current study suggest that CSI may be an effective instructional tool for teaching students at risk for MD because it prompts them to consider their background knowledge on the topic they are reading, to summarize key ideas, and to self-question while they read. In addition, it may be critical for ELLs at risk for MD to acquire skills that help them understand word problems because: (a) word problems become increasingly more abstract and complex beyond the second grade level, and (b) ELL students are unlikely to receive extra intervention support as math content becomes more challenging.

Finally, this study contributes to the math literature because EDM delivers a Dynamic Assessment Comprehension Strategy Instruction (DA-CSI) model in the native language. Results indicate that this may be an effective model because EDM was able to teach students math concepts, knowledge, and skills through the language they knew best. Because this intervention was developed in the native language, it may have provided a more efficient language medium to express thought, which is critical to students' comprehension development. In addition, the emphasis of the native language stressed the importance to students that mathematical proficiency is built upon the activation of prior knowledge and applying what has been learned to the acquisition of new math concepts and skills related to word problem solving development. As a result, EDM may be an effective instructional method for ELLs because it incorporates comprehension strategies in the native language that allows them to understand word problems so that they can access the general math curriculum.

Limitations

Although the results of this multiple baseline study demonstrate the effect of a word problem solving intervention that positively mediated ELLs' word problem solving skills, there were limitations to this study. First, intervention data were collected on an individualized basis over a duration of 17 sessions. Therefore, the extent to which the intervention may improve word problem solving skills in other students with similar learning challenges for this time duration is unknown. Next, this pilot study suffers from a small sample size (six students), and because of this, generalizing intervention effectiveness to other populations is limited at this time and further replication is required with larger samples. Finally, to date there have been few math studies conducted in the native language of ELLs. Although EDM was developed based on research that promotes evidence-base instruction, focusing on the native language (e.g., math vocabulary) may have influenced students' performance, rather than solely on DA or CSI. Clearly, additional research on a larger and longitudinal scale on the properties of DA and CSI is needed, especially studies linking the effectiveness of these two constructs to students' native language in math.

Implications

The findings from this study have implications for ELLs at risk for MD and their elementary math curricula. Although participants had a fundamental understanding of numbers in their native language, achievement data collected prior to the study indicated that the participants' skill was limited to number calculations (simple math problems) and heavily influenced by the context in which the numbers appeared. This below-basic proficiency meant that EDM provided students with extensive opportunities to learn and practice math concepts and content in their native language, while learning to use their background knowledge in improving math comprehension skills. Word problem solving data indicated that the students could acquire proficiency (i.e., solve a word problem correctly) with Level 1 Spanish word problems once given appropriate vocabulary and comprehension strategies. As an example, once students were taught basic math vocabulary and concepts and given time to practice with math problems, they could solve these problems quite easily. However, it was only when they moved on to more complex word problems that solving these types of word problems became more challenging because these students needed more instruction that emphasized comprehension strategies, vocabulary, and oral language practice.

In summary, results from this study indicate that comprehension strategy training situated within a dynamic assessment framework could satisfy the learning needs of certain ELLs, particularly those who may be struggling with math disability at the elementary level. The DA-CSI based EDM intervention strategy employed in this study can be an effective learning tool for teachers with ELL students because it helps define (a) what the ELL student demonstrated independently (present ability), and (b) what the ELL student could achieve with systematic assistance (potential ability), giving teachers an appropriate instructional tool where they can create a baseline to work from and a stronger idea of expected progress. Additionally, when ELL students learn to use the strategy effectively and efficiently, they should become more independent learners, allowing them to progress further on their own.

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Appendix A

Estratégica Dinámica de Matemáticas (EDM) Probe Sheet (English Translation in Parenthesis)

Examinador, “Un problema de palabras hace una pregunta. ¿Puedes encontrar la pregunta en el siguiente problema de palabras?“

(Examiner, “A word problem asks a question. Can you find the question in the following word problem?”)

Examinador, “En cada pregunta siempre hay palabras importantes. ¿Puedes subrayar las palabras en esta pregunta que piensas que son importantes para resolver este problema?”

(Examiner, “In each question there are always important words. Can you underline words in this question that you think are important to solving this problem?”)

Examinador, “En cada problema de matemáticas siempre hay números que necesitas para resolver el problema. Puedes círcular los números que necesitas para resolver este problema?”

(Examiner, “In each math problem there are always numbers that you need to solve the problem. Can you circle the numbers that you need to solve this problem?”)

Examinador, “Los números se utilizan para formar y resolver un problema de matemáticas. ¿ Puedes utilizar estos números para formar el problema de modo que puedas resolver el problema de la palabra?”

(Examiner, “Numbers are used to set up and solve a math problem. Can you use these numbers to set up the problem so that you can solve the word problem?”)

Examinador, “Después de resolver el problema de matemáticas, debes de revisar la respuesta. Puedes comprobar tu respuesta?”

(Examiner, “After solving the math problem, you need to check your answer. Can you check your answer?”)

Appendix B

English Vocabulary Translation

This is the vocabulary word *sum*. The word sum can mean *more*, *to add*, *to combine* and can be represented with the math sign (+). (On the chart board the teacher interventionist wrote +, *to add, to combine.* Next, the teacher interventionist contextualized this vocabulary.) "Julio went to the market and bought 5 packets of red rocks and 5 packets of blue rocks for his fish bowl. What is the sum of the products? What does the word sum mean (writing *sum* on the chart board)? *Sum* means to combine (+). What is the sum of all the products? 5+5 = 10. Now can you give an example?” Student, “I went to the store and I bought three packets of red rocks and three packets of blue rocks for my fish bowl.” Teacher interventionist, "What is the sum?" Student, "Sum means to combine. Three plus one equals four (3+3 = 6)." Teacher interventionist, "Very Good!"

Appendix C

Estratégica Dinámica de Matemáticas Cue Sheet (abbreviated example)

Ejemplo de problema de palabras: Dora tiene $17.00 en su alcancía de cochinito. Para su cumpleaños, sus abuelos le dieron $10.00. ¿Cuál es la cantidad *total* de dinero que Dora tiene en su alcancía de cochinito?

Examinador, “Un problema de palabras hace una pregunta (apunta a la pregunta): ¿Cuál es el *total* de dinero qué Dora tiene en su alcancía de cochinito? Después, subrayaré las palabra(s) importantes en la pregunta.

Examinador, Sé que Dora tiene *dinero en su* alcancía de cochinito. ¿Qué significa la palabra *total*? No entiendo esta palabra *total*. Vamos a ver si voy a la tienda y quiero comprar dulces, el cajero me dará el *total* de lo que tengo que pagar. *Total* significa todo junto o *suma* o *agregar*. Si puedo reemplazar o sustituir la palabra *total* con *suma* tiene esto sentido?¿Cuál es la suma de dinero que Dora tiene en su alcancía? Sí, esto tiene sentido. Total también puede significar *suma* o *agregar*(+).

Examinador, ¿Cuál es el total de dinero que Dora tiene en su alcancía de cochinito? El problema de palabras, dice que Dora tiene $17 dólares en su alcancía de cochinito. Para su cumpleaños, sus abuelos le dieron $10.00. ¿Cuál es el *total* de dinero que Dora tiene en su alcancía de cochinito? Voy a circular estos números, ya que estos son los números que necesito para resolver este problema. Bueno, vamos a resolver este problema. Necesitamos *agregar* o *sumar* $17.00 + $10.00 = $27.00. Mi respuesta es $27.00; Dora tiene $27.00 dólares en alcancía de cochinito.

Examinador, "Bueno, necesito revisar mi respuesta. Si comienzo con 17 y cuento de un dólar (diezveces), yo cuento 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, mi respuesta es 27 dólares. Esto es correcto. Dora tiene 27.00 dólares en su alcancía de cochinito. Ahora es.

Appendix D

Estratégica Dinámica de Matemáticas Cue Sheet (English translation)

Word Problem Example: *Dora has $17.00 in her piggy bank. For her birthday, her grandparents gave her $10.00. What is the total amount of money that Dora has in her piggy bank?*

Examiner, "A word problem asks a question (point to the question): What is the total amount of money that Dora has in her piggy bank? Next, I will underline the important word(s) in the question."

Examiner, "I know that Dora has money in her piggy bank. What does the word *total* mean? I do not understand this word *total*? Let's see if I go to the store, and I want to buy candy, the cashier will give me a *total* amount to pay. *Total* means *all together* or *sum* or *to add*. If I replace or substitute the word *total* with *sum* does this make sense? What is the *sum* amount of money that Dora has in her piggy bank? Yes, this makes sense. *Total* can also mean to *sum* or to *add* (+).

Examiner, "What is the total amount of money that Dora has in her piggy bank? The word problem says *Dora has $17.00 in her piggy bank. Her grandparents gave her $10.00. What is the total amount of money that Dora has in her piggy bank?* I am going to circle these numbers, as these are the numbers I need to solve this problem. Okay, let's solve the problem. We need to add or sum $17.00 + $10.00 = $27.00. My answer is $27.00; Dora has $27.00 in her piggy bank.

Examiner, "Okay, I need to check my answer. If I start with 17 and count by one dollar (ten times), I count 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, my answer is 27 dollars. This is right. Dora has $27.00 dollars in her piggy bank. Now it is your turn."