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Effects of Reading Strategy Intervention on Math Word Problems in Bilingual School-Age Students With Math Difficulties

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EBP Briefs

Structured Abstract

Clinical Question: Do bilingual school-age children (P) who receive reading strategy alone interventions (I) show improvement in math word problems (O) relative to a multiple-target intervention or control condition (C)?

Method: Systematic Review

Study Sources: PsycInfo®, Web of Science, JSTOR, PubMed, ERIC

Search Terms: "bilingual*" OR "second language learner" OR "language learner" OR "English as a second language" OR "English as a foreign language" AND "math word problem" OR "math applied problems" AND "intervention" OR "treatment" OR "therapy" AND "school-age" OR "elementary" OR "primary" OR "grade"

Number of Included Studies: 12

Primary Results:
Bilingual students with math difficulties showed improvement in math word problems from reading strategy interventions and reading strategy interventions with math vocabulary instruction, content knowledge priming, and culturally relevant approaches.

Bilingual students and teachers generally had positive feedback on various intervention approaches.

Conclusions:
An overall aim of reading strategy interventions for bilingual students with math difficulties is to actively regulate their reading behaviors to reduce the cognitive load on linguistic information to focus on solving math word problems. There are two high-level pieces of evidence showing that bilingual students with math difficulties benefit from reading strategy interventions alone or in combination with content knowledge priming. However, additional research is needed to evaluate the effectiveness of including math vocabulary instruction, the use of a culturally relevant approach, and the comparison of different reading strategies. These approaches only have minimal evidence (primarily single-subject design studies) yet have high social validity.

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Clinical Scenario

Wendy, a bright and enthusiastic Spanish-English third-grade student, was facing challenges with math word problems in her dual language immersion program. She currently receives instruction in both languages using a 50/50 model. She received math education in Spanish from kindergarten to second grade and in English from third grade onward. Her numerical operation skills were within the typical development range. However, her math word problem skills were far below average compared to her grade. She was diagnosed with developmental language disorder (DLD) using the converging evidence framework by Castilla-Earls et al. (2020). Her parents and classroom teacher indicated concerns about her language development in terms of semantics, morphosyntax, and pragmatics. Her narrative retell language samples in both Spanish and English showed that the percentage of grammatical utterances was less than 60% for both languages and the mean length utterance was 1.5 and 2.25 *SD*s (standard deviations) below the age norm in Spanish and English, respectively. She scored 1.5 *SD*s below the age norm for Spanish and 2.5 *SD*s below the age norm for English with reference to standardized test results on semantics, morphosyntax, and narratives. She has an Individualized Educational Program (IEP) and currently receives weekly speech and language therapy. Her teacher, noticing Wendy's struggles, wondered if her bilingualism might be a factor affecting her comprehension given that her family only speaks Spanish at home. The teacher decided to consult with the school's speech-language pathologist (SLP) during an IEP meeting to explore potential strategies that could assist Wendy in overcoming these difficulties.

The SLP stressed that bilingualism is not a risk factor for language impairment (Peña et al., 2023). The SLP specifically pointed out that the high Spanish exposure at home, previous math education in Spanish, and higher oral language performance in Spanish over English might help Wendy and support her math knowledge in the classroom. However, the SLP suggested that because of Wendy's diagnosis of DLD, there might be specific strategies to enhance her comprehension of math word problems. The SLP proposed meeting with Wendy to introduce and practice strategies that could aid her in understanding and solving these types of math challenges. For instance, the SLP could engage Wendy in exercises that encourage her to paraphrase questions; visualize problems; use drawings or diagrams; or break down the problems into smaller, more understandable parts. The SLP could also prompt Wendy to relate the math problems to real-life scenarios, encouraging her to think about the problems in both of her languages.

The teacher, in collaboration with the SLP, planned a session with Wendy to introduce these strategies and to provide her with tools to navigate math word problems more effectively taking into account her full linguistic background. The collaborative effort between the teacher and the SLP was intended to empower Wendy with a set of techniques to enhance her math problem-solving skills. Although these strategies initially seemed promising, the teacher noticed Wendy's inconsistent performance and began to question the effectiveness of each strategy to aid her comprehension. The teacher asked if there is any reading strategy to support Wendy's development. She also wondered if other social and cognitive factors might be at play.

Background Information

The challenges of math word problems for some bilingual students can be explained by the difference in their cultural knowledge and language development. Math word problems might require additional cognitive load for some bilingual students to comprehend the linguistic information of the prompt, integrate the language content and math concepts, and represent the information in the form of math expression, especially for students with limited proficiency in the language of instruction (Kingsdorf & Krawec, 2014). With reference to the cognitive demand for language comprehension in math word problems, interventions on reading comprehension strategies might be conducted to

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examine the effectiveness of improving math word problems in bilingual students with mathematical difficulties (MD).

Application of successful reading strategies requires executive function, which can be supported by early childhood bilingualism (Hartanto et al., 2019) yet might pose a challenge for bilingual language transfer (Kempert et al., 2011). These conflicting findings can be further disambiguated with a review that systematically structures what is already known about strategy-based reading comprehension interventions. Furthermore, some bilingual students with limited proficiency in the language of instruction might encounter challenges in processing the linguistic complexity of math word problems. Language is thought to be of particular importance because children use mathematics-specific vocabulary and syntax to make sense of mathematics. The use of their first language to understand mathematics meaning also plays a role in how this information is transferred to English (Kazima, 2007; Peng et al., 2020). This review helps teachers and clinicians evaluate the validity of available interventions.

Instructional approaches that consider and incorporate students' identities are critical contexts for learning (Esteban-Guitart & Moll, 2014). Such approaches help build a dynamic relationship between the student's home/community and school (Ladson-Billings, 1995). Culturally relevant pedagogy is a theoretical model that posits practitioners need to support students' achievement, support their acceptance and affirmation of their cultural identity, and foster advancement of critical perspectives that challenge inequities (Ladson-Billings, 1995). Culturally relevant pedagogy can be implemented in different ways including using bilingual instruction, supporting and encouraging the use of home language, and using culturally relevant content and materials.

Wendy's home language is Spanish. She has developed conceptual representation of some mathematical concepts in Spanish through both home and school experiences. When Wendy is home, she engages in routine activities with different family members. She knows when to give her dad a screwdriver that is *plano* (flat) rather than one that is shaped like a *cruz* (cross). She also understands that she needs to add twice as much of an ingredient to a recipe if her grandma tells her to add *doble* (double). Her favorite activity is grocery shopping with her mom because she has the opportunity to weigh vegetables and fruits by *agregando* (adding) or *quitando* (subtracting) items as needed. Overall, Wendy has developed a certain degree

of Spanish proficiency and conceptual representation of some mathematical concepts that her teacher can leverage in intervention. It is important to consider the potential effect of culturally and linguistically relevant approaches on Wendy's intervention outcomes.

Clinical Question

The clinical question for this study is: Do bilingual school-age children (P) who receive reading strategy alone interventions (I) show improvement in math word problems (O) relative to a multiple-target intervention or control condition (C)?

Search for the Evidence

To be included in this review, studies must (a) include bilingual school-age students, (b) describe an intervention design, (c) measure math word problems as an outcome, (d) present original research, (e) be published in a peer-reviewed journal, and (f) report in English. All research designs along the evidence hierarchy (e.g., case study, pre-post nonexperimental, randomized controlled trial) were included for consideration, and the duration of the intervention was free to vary.

PsycInfo, Web of Science, JSTOR, PubMed, and ERIC databases were searched using the following terms: ("bilingual*" OR "second language learner" OR "language learner" OR "English as a second language" OR "English as a foreign language") AND ("math word problem" OR "math applied problems") AND ("intervention" OR "treatment" OR "therapy") AND ("school-age" OR "elementary" OR "primary" OR "grade"). The initial search provided 91 references which included 13 duplicates. Seventy-eight unique references in total were imported to the application Covidence for the screening and extraction process. Wendy's SLP (first author) performed the title and abstract screening for all references while a colleague (second author) performed a second-rater reliability check on 20% of the references. The inter-rater reliability was 94% (15/16) and the single inconsistency was resolved by discussion.

A subset of 24 articles was further screened at the full-text level using the criteria mentioned above. The first author screened all full texts while the second author performed a second-rater reliability check on 20% of them. The inter-rater reliability was 90% (9/10), and the inconsistency was resolved by discussion. After reading all

the articles, 12 articles met the inclusion criteria. Figure 1 shows the search and selection process.

Extraction of Findings

Study information was extracted for synthesis by the first author on all 12 included articles into a Microsoft® Excel® workbook. There were three major areas for data extraction: participant characteristics, intervention characteristics, and intervention outcomes. The participant characteristics extracted included the sample size, sex, age (both mean and range), race, language(s) spoken, and exposure of the participants. Moreover, the description of the intervention was extracted together with language domains/skills targeted in the intervention. The extracted intervention outcomes consisted of the math word problem outcome measures and the statistics reported. The math word problem measurements adopted in the studies were extracted with information on answer method(s) and reliability. For the statistics reported, the mean and standard deviation of the measurements were extracted at pretest, posttest, and follow-up assessment if they were reported. The statistical analysis adopted to measure the difference in reading comprehension ability was extracted with the statistical test(s) conducted, statistical coefficient(s), and the significance level. In total, 12 articles were identified for inclusion in the review. Tables 1 and 2 summarize the included articles for reading strategy alone interventions and interventions targeted at multiple skills. Reading strategy alone intervention means the intervention only focuses on the use of explicit cognitive strategies to decode words, understand meanings and relationships between words, and facilitate the understanding of the context (Duke & Cartwright, 2021). Interventions that target multiple skills, such as content knowledge priming and vocabulary learning, are summarized in Table 2.

Evaluating the Evidence
Summaries of Included Studies

The 12 included articles can be organized into three major categories based on the targeted skills in the intervention, namely (1) reading strategy alone interventions, (2) reading strategy with content knowledge priming, and (3) reading strategy with vocabulary instruction. Only the intervention and outcome measures in

Orosco (2013) were conducted in Spanish, whereas all other interventions and outcomes were conducted in English.

Reading Strategy Alone Interventions

There were three studies, including one randomized controlled trial and two single-subject experimental designs, examining the efficacy of reading strategy alone interventions. All three studies examined paraphrasing as the targeted reading strategy. Swanson et al. (2019) recruited 71 Spanish-English third-grade students who were classified as English language learners (ELL) and 37 Spanish-English third-grade students who were classified as ELL and MD in a randomized controlled trial. They investigated the effectiveness of three types of paraphrasing strategies (i.e., paraphrase and restate the question, paraphrase relevant information, and completely paraphrase all propositions) compared to control conditions. Students completed both written and oral math word problems in pre- and posttests. Results showed that paraphrasing relevant information—which restricts paraphrasing to questions, goals, and needed numbers—yielded a significantly higher gain in both written and oral math word problem accuracy in bilingual students compared to the other two conditions. However, bilingual students with math difficulties had lower gains compared to bilingual students without math difficulties.

Kingsdorf and Krawec (2016) conducted a single-case multiple baseline design study with 10 bilingual third-grade students with different first languages on the efficacy of paraphrasing and visualizing math word problems. The intervention first used a think-aloud procedure then adopted a self-monitoring checklist on paraphrasing and visualizing the problems. All students showed improvement in math problem-solving. Similarly, Kong and Swanson (2019) conducted a single-case multiple baseline design study with nine Spanish-English bilingual third-grade students on the explicit instruction of paraphrasing strategy. The strategy had four steps: paraphrasing the known information, paraphrasing the important information, crossing irrelevant information, and solving the problem. All students showed improvement in math problem-solving, yet the effect size of the intervention was small.

Reading Strategy With Content Knowledge Priming

There were two studies, including one randomized controlled trial and one single-subject experimental design, examining the efficacy of reading strategy and content

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knowledge priming interventions. King and Powell (2023) implemented a randomized controlled trial with 304 predominantly Spanish-English bilingual third-grade students with math difficulties on the efficacy of the Pirate Math intervention compared to no intervention. The Pirate Math intervention consisted of math calculation and equal sign interpretation review, followed by instruction on an attack strategy (i.e., read the problem, underline and cross out information, and name the problem type). Results showed that students had significantly higher improvement in math word problems after the intervention compared to the no-treatment condition. Driver and Powell (2017) conducted a single-case multiple baseline design study with nine bilingual third-grade students with different first languages on the efficacy of the RISE (i.e., read, illustrate, solve, and explain) strategy together with content knowledge related to the problems. All students improved on the math word problem in the posttest.

Reading Strategy With Vocabulary Instruction

There were seven single-subject experimental studies examining the efficacy of reading strategy and vocabulary instruction. Orosco (2013, 2014a, 2014b) and Orosco et al. (2013) evaluated the efficacy of Dynamic Strategic Math (i.e., know it, find it, set it up, solve it, and check it) in English and Spanish with Spanish-English bilingual second- and third-grade students, respectively. The intervention first taught specific math concepts and vocabulary before introducing Dynamic Strategic Math. Participants showed improvement in math word problems across age groups and languages of instruction. Luevano and Collins (2020) evaluated the efficacy of schema instruction with embedded vocabulary instruction with four Spanish-English bilingual second-grade students. All students improved on the math word problem solving. Orosco and Reed (2023) evaluated the efficacy of teaching multiple strategies with embedded vocabulary instruction to nine Spanish-English third-grade students, and students showed improvement throughout the intervention. Sanford et al. (2020) implemented the PLUSS (i.e., preteaching, language modeling, using organizers, systematic instruction, and strategic use) framework for four Spanish-English fourth-grade students. The intervention had embedded vocabulary instruction and content knowledge priming. Students showed improvement in math problem-solving.

Culturally and Linguistically Relevant Approaches

Five studies in the review included aspects of bilingual instruction. All of them strategically used the students' home language (Driver & Powell, 2017; Luevano & Collins, 2020; Orosco, 2013, 2014a; Sanford et al., 2020). Only Luevano and Collins (2020) included a preference assessment and explicitly used students' own ideas and experiences in the intervention. Students had positive feedback on the culturally and linguistically relevant approaches.

There were nine and 10 studies reporting social validity and fidelity, respectively. All interventions had overall positive feedback from students and teachers and high fidelity from inter-rater agreement.

Appraisal of Study Quality

To assess the risk of bias, Quality Assessment of Controlled Intervention Studies and Quality Assessment Tool for Case Series Studies were adopted to assess the risk of bias for included studies based on the intervention design (National Institutes of Health, 2021). The study quality was good for the two randomized controlled trials (i.e., King & Powell, 2023; Swanson et al., 2019) in terms of participant information, comparable groups, and outcome reports. However, the blinding information on treatment allocation and assessment was not reported in either study. The 10 single-case design studies had good ratings on the quality of participant information, intervention description, and detailed results. However, only four studies (i.e., Orosco, 2013, 2014a, 2014b; Orosco et al., 2013) documented the effect of follow-up assessment.

The Evidence-Based Decision

After reading through the studies and considering the quality of evidence, the SLP was able to answer the PICO question (i.e., whether reading strategy alone interventions produced better math word problem outcomes than multiple-target intervention or control conditions in bilingual students). The three studies that focused on reading strategy alone interventions (i.e., Kingsdorf & Krawec, 2016; Kong & Swanson, 2019; Swanson et al., 2019) showed improvement in math word problems, and one of them had the highest methodological quality in terms of design among the 12 studies. These three studies support the use of reading strategy alone interventions, such

as paraphrasing, as a technique for support. Furthermore, the 12 studies included in the current review were individual or small-group interventions, similar to the service delivery model that Wendy currently receives. In this regard, the intervention approaches had good external validity. Additionally, the included studies generally had high social validity and fidelity. Thus, the SLP suggests that Wendy's teacher could apply the technique in small group instruction and Wendy should be responsive to the intervention approach. The SLP suggests collaborating with the teacher to introduce paraphrasing as a strategy for Wendy. In this approach, the SLP will first introduce and practice paraphrasing with Wendy during the session for the language comprehension target and targets with math concepts. Then, Wendy's teacher should paraphrase the relevant information only, not the question or all propositions. The teacher can teach the paraphrasing strategy to Wendy.

Given that Wendy has higher proficiency and more language exposure in Spanish, the SLP recommends that Wendy's teacher consider incorporating a culturally and linguistically relevant approach in teaching. Although the five studies that adopted culturally and linguistically relevant procedures (i.e., Driver & Powell, 2017; Luevano & Collins, 2020; Orosco, 2013, 2014a; Sanford et al., 2020) were single-case designs, students improved in math word problems. They provided positive feedback on the intervention, indicating enjoyment of the intervention and effectiveness in learning and using strategies. The SLP decides to include culturally relevant concepts and vocabulary to support and encourage the use of the home language during therapy sessions. This can facilitate translanguaging practices and enable Wendy to use all her available linguistic resources during communication. In addition, Wendy's teacher can support and encourage the use of her home language (i.e., Spanish), which is her better language, during the classroom instruction. For example, Wendy's teacher can embed math vocabulary in Spanish during one-on-one teaching interactions. The SLP and Wendy's teacher can also explicitly incorporate Wendy's ideas and experiences into the word problems, so Wendy is more familiar with the context of the math word problems. Using familiar examples can help reduce the linguistic demand for processing information in word problems.

Given that Wendy's English language proficiency is 2.5 SDs below the age norm, she might have difficulties in learning mathematical knowledge and terminology in

spoken form, especially for different words representing the same math concepts and multiple-meaning words. Embedded English math vocabulary instruction might also be needed to facilitate her understanding of math concepts. Although the seven included studies on math vocabulary and reading strategy instruction were single-case designs, the math vocabulary instruction was short in duration (approximately 5 minutes at the beginning of the session or right after the introduction of the word problems). Wendy's teacher can share the math vocabulary list with the SLP so the SLP can work collaboratively with teachers to facilitate the understanding of math vocabulary (see Lowe et al., 2022, for different intervention approaches). Sharing the vocabulary list can make it feasible to implement math vocabulary instruction together with reading strategy intervention when needed.

To conclude, the current review found that all available evidence supported the use of reading strategy intervention. However, the evidence for incorporating other elements, such as content knowledge priming, vocabulary instruction, and use of culturally and linguistically relevant approaches, was relatively lower in quality, and there were no studies comparing these tactics with a reading strategy alone intervention. Note that the current evidence is promising, but it is not strong enough conclusively to identify the most effective reading strategy for math word problems. Thus, considering Wendy's bilingual language profile, the SLP and Wendy's teacher decide to work jointly, using paraphrasing as the targeted reading strategy with Wendy. For individual support, the SLP and teacher can teach Wendy to use her home language to paraphrase relevant information only and can use embedded vocabulary instruction of math concepts whenever necessary.

Authors' Note

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Table 1. Summary of Included Studies on Reading Comprehension Strategies Alone

Citation	Type of study	Participants	Strategies taught	Intervention	Outcomes
Kingsdorf & Krawec (2016)	Single-subject multiple baseline design	10 bilingual third-grade students (six Spanish-English bilinguals, one Serbian-English bilingual, one Hebrew-English bilingual, one French-English bilingual, and one Spanish-Portuguese-English trilingual). One typically developing student, six at risk of MD, two with specific learning disability, and one with intellectual disability	Paraphrasing	3 times per week, total duration varied	All students had improvement on math word problems.
Kong & Swanson (2019)	Single-subject multiple baseline design	Nine bilingual third-grade students with MD	Paraphrasing	30-minute sessions, 2–3 times per week, totaling 7.5 hours	All students had improvement on math word problems with the weighted average Tau-U of .53.
Swanson et al. (2019)	RCT	71 ELL third-grade students and 37 ELL third-grade students with MD	Paraphrasing	30-minute sessions, 2 times per week, totaling 15 hours	Students in paraphrasing relevant information group had significant higher improvement compared to paraphrasing all proposition group and control conditions. ELL students with MD had smaller improvement compared to ELL students without MD.

Note. No culturally responsive approach adopted in above studies. ELL = English language learners; MD = mathematical difficulties.

Table 2. Summary of Included Studies on Multiple Skills

Citation	Type of study	Participants	Strategies taught	Other targeted skills	Culturally responsive approach	Intervention	Outcomes
Driver & Powell (2017)	Single-subject design	Nine third-grade students (eight Spanish-English bilinguals, one Arabic/Nuba-English bilingual) who were ELL and at risk of MD	RISE strategy and schema instruction	Content knowledge related to the problem	Use of native language and explicit use of students' own ideas and experience	25-minute sessions, 3 times per week, totaling 12.5 hours	All students had improvement on math word problems in terms of raw score and percentile rank.
King & Powell (2023)	RCT	304 bilingual third-grade students with MD	Schema instruction	Content knowledge on math concepts (equal sign or skill review)	No	30-minute sessions, 2–3 times per week, totaling 22.5 hours	Intervention condition improved significantly compared to no intervention group with Cohen's *d* at 1.65.
Luevano & Collins (2020)	Single-subject multiple baseline design	Four Spanish-English bilingual second-grade students who were ELL and with low math skills	Schema intervention	Embedded vocabulary instruction	Use of home language and information from culture and preference assessment	45-minute sessions, 2 times per week, total duration varied	All students had improvement on math word problems and were able to identify the math vocabulary.
Orosco (2013)	Single-subject multiple baseline design	Six Spanish-English bilingual second-grade students who were ELL and at risk of MD	Estrategia de Matemáticas Dinámicas (Dynamic Strategic Math)	Math vocabulary and concept instruction	Use of home language instruction	25-minute sessions, 3–4 times per week, total duration varied	All students had improvement on math word problems in posttest and follow-up assessment.
Orosco et al. (2013)	Single-subject multiple baseline design	Six Spanish-English bilingual second-grade students who were ELL and at risk of MD	Dynamic Strategic Math	Math vocabulary and concept instruction	No	25-minute sessions, 3–4 times per week, total duration varied	All students had improvement on math word problems in posttest and follow-up assessment.
Orosco (2014a)	Single-subject multiple baseline design	Six Spanish-English bilingual third-grade students who were ELL and at risk of MD	Estrategia de Matemáticas Dinámicas (Dynamic Strategic Math)	Math vocabulary and concept instruction	Use of home language instruction	25-minute sessions, 3–4 times per week, total duration varied	All students had improvement on math word problems in posttest and follow-up assessment.
Orosco (2014b)	Single-subject multiple baseline design	Six Spanish-English bilingual third-grade students who were ELL and at risk of MD	Dynamic Strategic Math	Math vocabulary and concept instruction	No	25-minute sessions, 3–4 times per week, total duration varied	All students had improvement on math word problems in posttest and follow-up assessment.
Orosco & Reed (2023)	Single-subject multiple baseline design	Nine Spanish-English bilingual third-grade students who were ELL and at risk of MD	Problem-solving strategy	Embedded math vocabulary instruction	No	30-minute sessions, totaling 6 hours	All students had improvement on math word problems with the weighted average Tau-U of .38.
Sanford et al. (2020)	Single-subject design	Four Spanish-English bilingual fourth-grade students with limited English proficiency and low math skills (one student with specific learning disability)	PLUSS framework	Math vocabulary instruction and priming background knowledge	Use of home language	Not reported	All students had improvement on math word problems.

Note. ELL = English language learners; MD = mathematical difficulties.

Figure 1. Search and Selection Process

Identification of new studies via databases

Identification

Records identified from:

Databases (*n* = 91)

JSTOR (*n* = 29)

Web of Science (*n* = 23)

Records removed *before screening:*

Duplicate records removed

(*n* = 51)

Screening

Records screened

(*n* = 78)

Records screened

(*n* = 51)

Records sought for retrieval

(*n* = 24)

Records not retrieved

(*n* = 0)

Reports assessed for eligibility

(*n* = 24)

Reports excluded:

No math word problems as an outcome (*n* = 1)

No intervention (*n* = 1)

No bilingual population (*n* = 2)

Not original research (*n* = 1)

Included

Total studies include in review

(*n* = 12)