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Guiding Preservice Teachers to Adapt Mathematics Word Problems Through Interactions with ELLs

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In this article, the authors present a framework for guiding elementary preservice teachers in adapting mathematics word problems to better meet English language learners' (ELLs) needs. They analyze preservice teachers' ELL adaptations implemented in a one-on-one setting. Through qualitative methods, four themes regarding implemented adaptations are identified: language adaptations, mathematical adaptations, tool/visual adaptations, and structural adaptations. The authors conclude that the framework was successful in helping preservice teachers learn about adapting curriculum by interacting with ELLs. Implications for teacher education are discussed.

KEYWORDS: ELLs, preservice teachers, mathematics education, word problems

For English language learners (ELLs), mathematics can be more challenging than other subjects, as there is an emphasis on both the language of words and the symbols of mathematics (Freeman & Crawford, 2008; Harper & de Jong, 2004; Moschkovich, 2002; Swanson, 2015). It has been argued that there is an interconnectedness of language, symbols, and visuals that are characteristic in learning mathematics and in learning the language of mathematics (O'Halloran, 2008). Nevertheless, meanings of words differ in common language versus mathematical language. For example, the word *leg* has two very different meanings: in mathematics it represents the sides of a right triangle, but commonly it is known as a limb used for walking (Simpson & Cole, 2015). Because of the development of both mathematics skills and language skills, it is imperative that ELLs' needs are considered when developing, implementing, and adapting lessons in mathematics (Ernst-Slavit & Slavit, 2007; Janzen, 2008; Martinello, 2008; Truxaw & Rojas, 2014). ELLs should have access to high quality, effective mathematics instruction that supports

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their development and considers their needs (Moschkovich, 2010, 2013). Reforms have been encouraged that offer multiple approaches to mathematics for different types of learners; these multiple approaches are aimed at providing opportunities of success for all students (see, e.g., Standards for Mathematical Practice in the Common Core State Standards[1]). However, success for ELLs often requires specific accommodations.

Because of the limited language skills of the vast majority of public school teachers, making accommodations to lessons to assist ELLs is not easy and requires careful consideration of what to teach and how to teach (Avalos, Medina, & Secada, 2015; Celedón-Pattichis & Ramirez, 2012; Goldenberg, 2013). Furthermore, there is a movement to embrace mathematics as more student-centered with a focus on thinking, communicating, and reasoning by requiring more than just computational understanding but also conceptual understanding (Bunch, 2013; Santos, Darling-Hammond, & Cheuk, 2012). Adapting curriculum to meet students' needs requires a skillset that must be developed and enriched over time through practice and experience (van Ingen & Ariew, 2015). And while researchers have encouraged the focus on meeting the needs of ELLs through teacher preparation courses and lessons (see, e.g., Darling-Hammond, 2010; Keengwe, 2010; Samson & Collins, 2012), there are still challenges in that preservice teachers (most often) are not being prepared to meet the needs of ELLs through their university training and coursework (Bunch, 2013). Most mathematics education preparation programs do not emphasize the instructional skills mathematics teachers need to address and meet the needs of ELLs (de Jong & Harper, 2005; Ernst-Slavit & Slavit, 2007; Freeman & Crawford, 2008). For instance, Durgunoglu and Hughes (2010) explored how prepared preservice teachers were to teach ELLs. They found that the participating preservice teachers of their study were neither well prepared to teach ELLs in their teacher education program nor were they provided with support in their placements to address their inexperience and lack of knowledge (also see Siwatu, 2011; Webster & Valeo, 2011).

In the university setting, preservice teachers must be provided with opportunities to grow as future teachers of ELLs by learning how to accommodate the needs of ELLs through lesson plan design (Lucas, 2011). It has been recommended that preservice teachers be provided with opportunities to better connect theory learned at the university with practice out in the classrooms (Grossman, Hammerness, & McDonald, 2009). Furthermore, field experiences can be beneficial in guiding preservice teachers' understanding of ELLs and their needs (Coady, Harper, & de Jong, 2011). Specifically, García, Arias, Murri, and Serna (2010) suggest an emphasis on developing knowledge of ELLs through contacting and collaborating directly with community members.

[1] See http://www.corestandards.org/Math/Practice/.

With the goal of providing preservice teachers with practical experience working with ELLs, we designed a project that integrated the content of an elementary mathematics methods course with implementing adaptations for ELLs in mathematics. Using a variety of guidelines described by researchers for adapting curriculum, preservice teachers in our study were asked to adapt text to better meet the needs of ELLs in mathematics. The specific emphasis was on mathematics word problems at the elementary school level. In this article, we aim to address the following question: When preservice teachers have the opportunity to adapt word problems to better meet the needs of an ELL in a one-on-one setting, what adaptations are employed?

Word Problems and ELLs

Word problems are often challenging for all learners because they encompass various cognitive processes. For example, learners need to access pre-stored information and to determine what algorithm to use and what information is pertinent and irrelevant (Orosco, Swanson, O'Connor, & Lussier, 2011). Given the complexities of language, ELLs face unique linguistic challenges when approaching mathematics and word problems (Abedi & Lord, 2001; Yeong & Chang, 2014). With these challenges in mind, it is important that there are considerations with respect to the demands of word problems on ELLs' mathematical and linguistic development.

Researchers have identified linguistic features that make a text difficult to read by slowing down the reader, making misinterpretation more likely, and adding to the reader's cognitive load (see, e.g., Abedi, Hofstetter, Baker, & Lord, 2001; de Jong & Harper, 2005). These indices of language difficulty include word frequency, word length, and sentence length, in addition to the overall length of the mathematical item, which is unique to mathematics word problems. Elsewhere (see, e.g., Gómez, Kurz, & Jimenez-Silva, 2011), we have provided a practice-based guide for adapting mathematics word problems for ELLs taking into account these described challenges. Adapting by simplifying the language of the text does not distort nor dilute the content concepts (Echevarria, Vogt, & Short, 2008). But rather, it reduces the readability demands by eliminating linguistic characteristics that get in the way of comprehension (Dyck & Pemberton, 2002).

There are benefits to keeping language simple for ELLs. An ELL who encounters familiar words will spend less time analyzing the task (Gathercole & Baddeley, 1993). ELLs perform better on mathematical items with shorter words and shorter sentence length because they are less morphologically and syntactically complex (Abedi, Lord, & Plummer, 1995). Lengthy items will take longer to complete given that ELLs on average read more slowly (Lepik, 1990). Adaptations of

word problems may help ELLs successfully engage in mathematics word problems by making the content more accessible (Swanson, 2015).

Language acquisition experts as well as teachers use the term *adapt* to refer to the adjustments that need to be made to any type of text to make it comprehensible for ELLs. Indeed, adaptation of content is one of the pillars of structured English immersion (SEI; Echevarria et al., 2008). There are generally two types of adaptations: accommodations and modifications. Generally, accommodations are "changes to materials or procedures that provide students access to instruction and assessments," while modifications are "defined as changes in…materials or procedures that *do alter* the content being measured" (Thurlow & Kopriva, 2015, pp. 333–334). Modifications change the content; accommodations do not. While modifications may be appropriate for students receiving special education services, most of the time educators should be providing *accommodations* for ELLs (Hite & Evans, 2006). In this article, we focus on making accommodations by adjusting word problems to best meet the needs of ELLs. Accommodations can support ELLs' access to curriculum; specifically, barriers can be removed so that opportunities to engage in the curriculum are provided to ELLs (López, Scanlan, & Gundrum, 2013).

Without language support provided by the teacher, ELLs could fall behind their peers (Swanson, Moran, Bocian, Lussier, & Zheng, 2013; Yeong & Chang, 2014). To stay abreast of their peers, ELLs need access to a continuous language-focused program across all subjects (Gibbons, 2002), including mathematics. Simple exposure to English does not guarantee that ELLs will learn the academic language and mathematics content. Consequently, the teacher needs to understand that integrating content and language requires systematic planning (Gibbons, 2002).

Adapting Curriculum for the ELL

Abedi and colleagues (2001) have identified indices to predict the difficulty of a text. Besides word frequency, word length, and sentence length, they discuss additional linguistic features that may cause difficulty for readers, including: passive voice constructions, long noun phrases, long question phrases, comparative structures, prepositional phrases, sentence and discourse structure, clause types, conditional clauses, and concrete versus abstract or impersonal presentations. Abedi, Courtney, Leon, Kao, and Azzam (2006) summarize research findings on adapting the language of word problems on tests. Their findings were used to structure the processes followed to guide the preservice teachers in our study:

- If the words are long, replace them with high frequency words that are easier to read;
- If words are unfamiliar, replace them with familiar words, omitting or defining words with double meaning or colloquialisms;

- If the sentences are long, retain subject-verb-object structure, begin questions with question words, and avoid clauses and phrases;
- If the item is long, remove unnecessary expository material; and
- If sentences are complex, keep to the present tense, use active voice, avoid the conditional mode, and avoid starting statements and questions with clauses.

In our study, we were interested in guiding preservice teachers in implementing these techniques to make changes to their background knowledge relating to adaptation of curriculum in mathematics. Part of the preparation involved some basic tenets for adapting material. Rhine (1995) found that in-service teachers were unable to properly gauge their ELLs' skills. In addition, the teachers had limited knowledge about how their ELLs think. We also wanted to address this disconnect by focusing on the ELLs' thinking along with the preservice teachers' understanding of the ELLs' mathematical and linguistic needs based on their interactions.

Methods

In a course deigned to prepare preservice teachers to meet the needs of ELLs, preservice teachers were asked to work one-on-one with any K–12 ELL student in their student-teaching placements. Because the preservice teachers were placed in such different school contexts, we worked with their specific needs based on their placement. The one-on-one ELL interactions were structured to focus on adapting the content of mathematics curriculum to better meet the ELL's needs while emphasizing the learning and growth of the preservice teacher as a result of the interactions.

Participants

The participants were elementary graduate preservice teachers working simultaneously on their elementary education degree and teacher certification in the state of Arizona. The course in which this study was conducted was designed to prepare preservice teachers for linguistically diverse classrooms in which there were ELLs learning content supported by SEI strategies. Preservice teachers were prepared to address linguistic and cultural awarenesses by learning strategies designed to meet the individual needs of ELLs based on language acquisition research. Because the course was open to all education majors (elementary, secondary, and special education), there was a diverse group of specializations. However, only those that focused on adapting curriculum in mathematics were included for analyses. Six preservice teachers concentrated on mathematics and completed all

the components of the assignment with an ELL. Four were women; all were White; all were elementary education majors.

Setting

States like California, Arizona, and Massachusetts that have adopted an English-only policy in K–12 education generally require that colleges of education build into their curriculum a place where mathematics education students acquire the knowledge and skills in language development to address the needs of both native and non-native speakers of English (Guo & Koretz, 2013; Parra, Evans, Fletcher, & Combs, 2015; Rolstad, Mahoney, & Glass, 2005). For example, in Arizona's state-mandated SEI courses, preservice teachers learn about the nature of language development and how language varies according to the context in which it is used. Coursework for preservice teachers explains that it is easier to learn language that is embedded in the visual context provided by manipulatives, other visual cues, and hands-on demonstrations and activities (Gibbons, 2002), which are commonly used in the mathematics curriculum. Preservice teachers are also taught that ELLs are supposed to learn English as well as learn *in* English.

There are two primary approaches to learning in regards to ELLs: English-only or bilingual instruction. While bilingual instruction is more often supported by research studies (Adetula, 1990; Moschkovich, 2007; see also Rolstad, Mahoney, & Glass, 2005 for a meta-analysis), states often discourage bilingual instruction preferring English-only (Guo & Koretz, 2013; Menken, 2013; Menken & Solorza, 2014). With English-only instruction as a common occurrence in states with significant numbers of ELLs (Menken, 2013), we approached our instructional framework with that in mind. Because the children were placed in English-only classrooms, the framework that guided the preservice teachers' data collection focused on meeting the needs of ELLs in an English-only setting. We recognized the importance of bilingual education but had to work within the framework required by the state.

In Arizona at the time of the study, there were two 3 hour-credit courses required of all teachers. The Arizona Department of Education established the curricula for the two courses. The courses cover history, policy, research, theory, and practices. In addition, topics such as culture, family role, politics, and standards were embedded into the course. The bulk of the time was spent on teaching strategies, including the adaptation of content. As explained, the course content focused on a multitude of curricular ideas. The task at hand was designed to fuse the content in a meaningful way that provided an opportunity to learn about ELLs from ELLs; the primary objective was to contextualize the theory learned in a university setting with actual ELLs out in the classroom. Preservice teachers were to learn theory in class and experience the theory in context with children.

Data Sources

The preservice teachers were asked to identify and work with an ELL in their student-teaching placements. The ELL could be in any grade level. Participating preservice teachers were asked to select an ELL at the speech emergence level of language acquisition or below. ELLs at this stage of language acquisition have received English instruction for at least one year. Their active vocabulary consists of around 3,000 words, and they generally have a good comprehension of contextualized information. They still make many pronunciation and grammar errors when producing simple sentences. Also, they are capable of reading basic vocabulary and writing simple sentences. The preservice teachers in this study received guidance in analyzing the linguistic demands of written mathematics word problems. (The instruction they received in this area is more specifically described in the *Adapting Curriculum for the ELL* section of this paper.) The ELLs the preservice teachers selected were from a variety of countries: China, Croatia, Korea, two from Mexico and one not specified (first language was Spanish). All of the ELLs the preservice teachers chose to work with were in elementary school. The oldest child was in fourth grade; the youngest was in first grade. The mathematical content area that the preservice teacher selected to implement with the ELL considerably varied because the content was based on what the placement teacher was teaching. There was complete freedom in terms of the study design in relation to the selection of mathematics word problems; however, there were sometimes limitations provided by the placement teacher (based on curricular goals or the structure of content). None of the preservice teachers noted any interaction or changes of the word problem by the placement teacher; all indicated that they implemented the accommodations without the placement teacher's feedback.

Data were gathered throughout the semester based on the preservice teachers' reflective responses to adapting curriculum and working with the ELLs. Data were based on the preservice teachers' responses to the prompts described; both a pre-response and post-response were collected. The preservice teachers followed the process outlined in Figure 1. When the preservice teachers wrote their reflections, they were asked to focus on the following prompts:

1. Explain who this student is. What is his/her background? How long has he/she been in this country? What is his/her first language? What other schools has he/she attended, and where are the schools? What is his/her ELL level? How old is he/she? What grade level is he/she in? Any other pertinent information? Provide details about your student.
2. Analyze the student's responses and/or actions to each of the four problems.
3. Problem #1
4. Problem #2

5. Problem #3
6. Problem #4
7. Did the student appear to understand the language of the problems? Explain and supply supportive evidence to back up your statements.
8. Did the student appear to understand the mathematics of the problems? Explain and supply supportive evidence to back up your statements.
9. What do you think this student needs to better understand the word problems?
10. If you were this student's teacher, how would you help him/her? What would you do?
11. Staple the student's work for each problem to the back of this reflection.

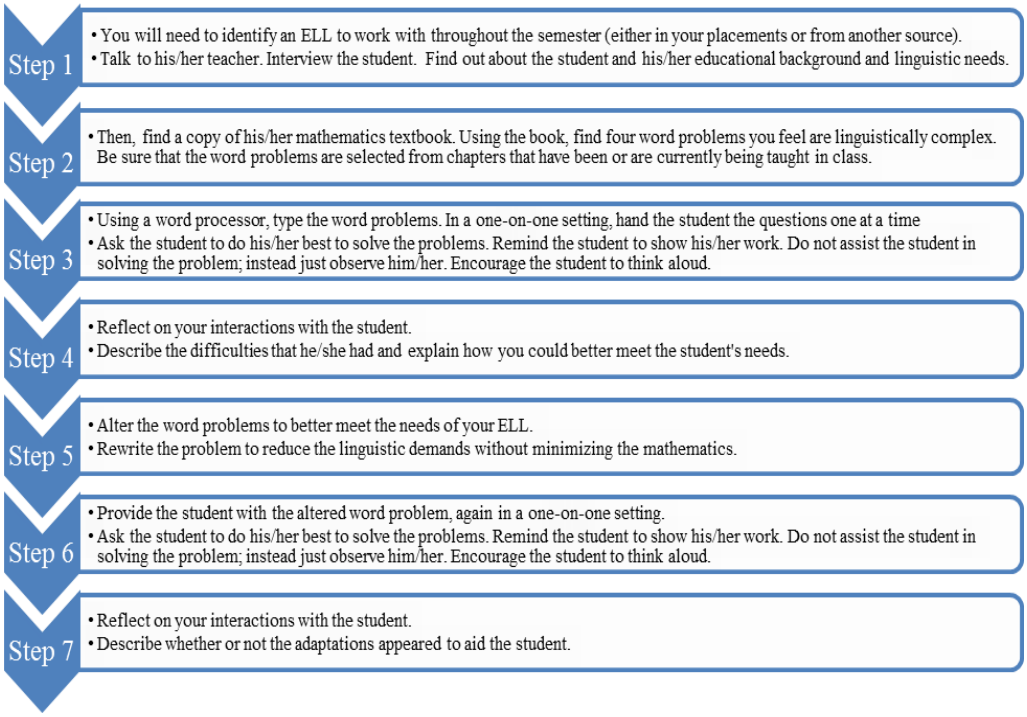

Figure 1. An outline of the steps followed by the preservice teachers during the semester.

When the word problems were administered after the readjustment, the same prompts were asked; however, there was an emphasis instead on the rewritten word problems. For example, the new question #6 read: "Revisit your answer to #6 in the first reflection. Would you still answer this question the same? Explain and support your stance." The preservice teachers did not prepare an interview script but were instead asked to question and interview by asking the ELL to solve the problem and

explain his/her reasoning by thinking aloud. They were also encouraged to ask follow-up questions of the ELL as needed.

When administering the word problems to the ELL, the preservice teachers were encouraged to read the problem aloud when requested or when they felt it would be helpful. The preservice teachers were also encouraged to talk to the ELL and to encourage think-alouds while they questioned the ELL's reasoning. They were discouraged from helping the ELL solve the problem or guide the solution of the problem.

Data Analysis

Using steps described by LeCompte (2000), the data were qualitatively analyzed: (a) tidying up, (b) finding items, (c) creating stable sets of data, (d) creating patterns, and (e) assembling structures. The term *data* refers to the preservice teachers' analyses of their interactions with the ELLs based on their pre- and post-responses to the prompts (see Figure 1). First, the data were identified and organized. This identifying/organizing involved sorting through all of the data for preservice teachers who emphasized mathematics specifically and making sure that paperwork and data were in order. Second, the process of finding items was initiated. We continually sifted through the preservice teachers' responses to the prompts to look for items that were relevant to the research questions. Next, we evaluated the data with an emphasis on both frequency and declaration with evidence (LeCompte, 2000). For example, if a preservice teacher said that she or he decreased word count it was verified by analyzing the original question with the changed version provided by the preservice teacher. After the items were identified, they were organized into groups. We then compared and contrasted the statements of the preservice teachers looking for an organized structure to their adaptations and analysis of their interactions. Patterns were then created in the fourth step. The items were reassembled into a coherent pattern to describe what adaptations were implemented and how they influenced knowledge of working with ELLs. These patterns were revisited and reevaluated throughout the data analysis until a cohesive taxonomy was identified. And finally, the structures were assembled to help build an overall description of the implemented adaptations (see LeCompte, 2000, for the complete steps).

Findings

Reflections from six preservice teachers were collectively analyzed. After following LeCompte's (2000) procedures, four themes were employed or suggested after the rewrite by the preservice teachers based on the analysis of their pre- and post-interaction prompt responses. These themes were: language adaptations, math-

ematical adaptations, tool/visual adaptations, and structural adaptations. Every adaptation made by the preservice teachers fit into one of these four broad categories. The impact the adaptation had on preservice teachers' learning in reference to their ELLs is discussed within each theme. To remain anonymous, the names of the ELLs were removed; they are simply referred to as the ELL. Commentary regarding success, failure, what worked or did not was from the participant (not us); it was not a discussion but simply results from the participants' experiences.

In terms of the mathematical content of the word problems, nearly all of the adjusted problems were Number and Operations (21/27). The other content came from Algebra (3/27), Geometry and Measurement (2/27), and Probability (1/27). (Some students decided to implement five questions instead of four, so the total number of questions adjusted was 27, not 24.)

Language Adaptations

Language adaptations were the most often implemented adaptation made by all six preservice teachers. When they implemented the word problems the first time they were able to observe difficulties the ELLs had with specific vocabulary words. One of the preservice teachers discussed the frustration he saw with his ELL in terms of the word problem: "He greatly needed teacher assistance to help break up the problem to simplify which data to use in order to correctly solve the word problem." This preservice teacher then made adaptations to the language (along with structural adaptations). He observed that "[The ELL] showed improved understanding for simplified text of the word problem. The answer provided…was incorrect due to poor mathematics…he was able to decipher [the] information needed to…answer the problem." Another preservice teacher supported his observations. She stated, "the integrity of the math problem was not damaged, the math problem was simplified in that the reading was only simplified not the math."

Another preservice teacher discussed issues with terms as well. She stated that the ELL struggles "with…his…unfamiliarity with the words bought and brought. The words appear very similar but indicate a very different action." She reduced the language demands for the ELL. In addition, she stated that there was too much unnecessary information that distracted from the mathematics: "it made it hard for him to determine exactly what was happening in the story and what math operation represented it." She found that her changes (simplifying vocabulary and removing unnecessary vocabulary) helped. The ELL seemed "very relaxed and confident…he didn't even ask for help or look at me."

An example of language adaptations can be seen in the following first-grade sample problem. The original problem was: "An Emperor penguin ate 13 fish for breakfast. At lunch, she ate some more fish. She ate a total of 23 fish. How many fish did she eat for lunch?" (Kyrene School District, 2009) The preservice teacher observed, "The wording of the problem prevented the ELL from following the ac-

tion of the problem. The complicated language made it more difficult for the ELL to understand the math." The revised problem read: "At sunrise, a bird eats 13 fish. At sundown, the bird eats some more fish. The bird eats 23 fish that day. How much did the bird eat at sundown?" The reflection of the preservice teacher stated, "I can see that the ELL has very strong math skills and is perfectly capable of solving complicated problems. She just needs the chance to use them by being able to understand what the problem is asking."

Mathematical Adaptations

There were various adaptations made in terms of mathematics as well—all six made adaptions relating to the terms. The preservice teachers adjusted the form of the numbers and the mathematical terms. Specifically, a preservice teacher replaced the numeric words with numbers (6 instead of six). This adaptation seemed to help, "using numbers instead of number words is always easier for a first grader."

Another preservice teacher questioned what to do when an ELL struggles with a critical term in mathematics. The ELL struggled with the term "quotient." The preservice teacher debated whether or not the term should be removed. He felt "uncomfortable removing the word quotient because of its significance in math vocabulary." In the end, he adapted the word problem removing the term quotient. He stated, "I felt that understanding the steps in the math calculation were more important than the labels used like quotient." The ELL was still unsuccessful. The preservice teacher believed that the lack of success was an issue with understanding what division means: "it is pretty clear…that his math skills are weak in understanding the components of a division problem." He recommended support for the ELL in the topic of division.

Some of the preservice teachers perceived difficulties in mathematical terms and concepts. For example, clarify mathematical terms is demonstrated in an adaptation of a fourth-grade sample problem.

> John has 10 pairs of white socks and 1 pair of blue socks in his drawer. There are no other socks in the drawer. Without looking, he takes 1 pair out of the drawer. What are his chances of choosing a white pair of socks? (Arizona Department of Education, 2009)
>
> a. Certain
> b. Impossible
> c. Likely
> d. Unlikely

The preservice teacher adjusted the problem as follows:

> In John's drawer, he has **only** 10 pairs of white socks **and** 1 pair of blue socks. Without looking, he takes 1 pair of socks out of the drawer. What is the probability of choosing 1 pair of white socks?

a. 100% chance
b. 0% chance
c. 91% chance
d. 50% chance

In the preservice teacher's reflection, she said, "[The ELL] stated that he liked having numbers as a choice as opposed to vocabulary."

Tool/Visual Adaptations

Some of the preservice teachers discussed the need for tools to support their ELLs while completing the word problems; this adaptation was made by three of the preservice teachers. One of the preservice teachers said, "He did not know the relationship between meters and centimeters. If I were his teacher, the use of [meter] sticks are the type of manipulatives this student could benefit by using to help learn the metric system." The preservice teacher with the ELL who struggled with division felt that "the use of manipulatives to better understand how to calculate a division problem" would be an important focus area for the ELL's teacher. Another stated, "I would use play money as a tool and allow him to practice handling money and counting it back in practice scenarios." Money would provide a visualization to connect the numeric value with the visual representation using currency. Moreover, some ELLs may not be as familiar with American currency and may need to gain experience.

Another preservice teacher used pictures to structure the simple addition problem. The first grade ELL was supposed to total the two quantities in the word problem. A preservice teacher stated that the rewritten problems "included pictures to represent the numbers in the word problems." The preservice teacher found that the ELL was much more successful with this adaptation. Another preservice teacher used pictures of the items described in the word problems. She stated, "Adding pictures…could have been too much guidance. Since he is an ELL, I felt adding pictures would help him, but I am not sure if it helped too much."

A sample provided by a preservice teacher originally read: "Solve. Farmer Dan had 37 rows of corn on his farm last year. This year, he has double that number of rows of corn. How many rows of corn does Farmer Dan have this year?" (Charles, Crown, & Fennell, 2004) The preservice teacher kept the sentences the same but added 37 pictures of corn. The preservice teacher stated that supplying pictures allowed the student to "work through the problems with greater ease than [the ELL] did with the first version…it took half the time."

Structural Adaptations

The preservice teachers also changed the structure of the problems; this adaptation was made by three of the preservice teachers. For example, one preservice

teacher broke up a word problem into smaller sentences that were written with one sentence per line rather than in paragraph form. After making her adaptations, she stated, "This layout was much better [for the ELL]; it was easier to read because the short sentences were broken up from each other. I just made it easier to pick out key phrases." The ELL was more successful when the preservice teacher altered the structure. Another preservice teacher stated, "In the rewrite of the problem, the arrangement of numbers was reversed to help emphasize the question of how much more." She stated that the adaptation helped the ELL better understand the mathematics contained in the problem. For example, a problem read: "16 penguins were playing in the ocean. 10 more penguins jumped into the ocean to play. How many penguins are playing in the ocean?" (Kyrene School District, 2009) The question was structurally adapted (along with language adaptations):

> 16 birds played in a tree
> 10 more birds came to play
> How many birds are playing in the tree?

In the reflection, the preservice teacher stated that the child made progress when answering the question:

> The first time she worked the problem, [she] seemed to rush through the problem…and just picked out two numbers from the problem and put them in a number sentence…the second time, [she] spent a great deal of time thinking…I simplified the problem so that she could follow the action.

Discussion

When the preservice teachers were provided with the chance to work one-on-one with an ELL, they were able to implement adaptations often discussed in theory. This implemented structure provided opportunities to move beyond theory written in a textbook to practice with an ELL. Preservice teachers were able to experience the complexities of making adaptations while noting the benefits (and sometimes obstacles as in the division example) the adaptations had on the ELL's understanding of mathematical word problems. Mihai and Pappamihiel (2012) have discussed the critical role of having preservice teachers engage with ELLs. The practices and insights learned in coursework are likely to be most effective once preservice teachers are working regularly with ELLs and have a clear understanding of the learning challenges ELLs face. In our case, the preservice teachers were clearly able to apply what they were learning in class in adapting the work for their ELLs.

The preservice teachers of this study successfully implemented the language adaptations described by Abedi and colleagues (2006). The preservice teachers were able to analyze a word problem and simplify the linguistic demands without

compromising the intent of either the word problem or the mathematics. While the intent of the word problems was not compromised, there were some issues with respect to compromising cognitive demand. For example, some of the preservice teachers seemed to guide the students too much (by producing pictures that really limited thinking and restricted multiple approaches or entry points) compromising students' thought processes. There seemed to be a focus on making sure the ELLs were able to get the right answer rather than providing opportunities to challenge the students at an appropriate mathematical level (that may or may not lead to a correct answer; Gillmor, Poggio, & Embretson, 2015; Kapur, 2014). In this study, we found that it was a challenge for preservice teachers to learn how to finesse word problems (or other problems for that matter) while still maintaining an appropriate and meaningful level of cognitive demand (Feldon, 2007; Schnotz & Kürschner, 2007).

Research has shown that mathematical items can be linguistically adjusted to reduce the language load without altering the construct being assessed (Sato, 2008; Swanson, 2015; Swanson et al., 2013). However, doing so requires that preservice teachers understand the ELL's level of English proficiency; in particular, understanding which words may be unfamiliar or challenging (Haag, Heppt, Stanat, Kuhl, & Pant, 2013). Numerous researchers have emphasized the importance of understanding ELLs' English proficiency levels in order to make such adaptations (Carr et al., 2009; Echevarria et al., 2008; Mihai & Pappamihiel, 2012; Wright, 2010). Preservice teachers were able to replace long and unfamiliar words with words that were easier to read or were more familiar. They also helped ELLs by breaking down sentences that were difficult in terms of their grammatical complexity and by using more familiar verb tenses (such as present tense). When preservice teachers changed the terms (e.g., the brought/bought example), they were able to experience the ELLs' difficulties within the context of learning.

The adaptation of mathematical terms implemented by the preservice teachers demonstrated their ability to make changes to try and meet the language needs of the ELLs. Although it is important that ELLs develop mathematical academic vocabulary, it is also important that teachers learn how to distinguish between terms that comprise essential mathematical vocabulary (Abedi, 2006). This form of adaptation posed some difficulty for the participants as evidenced in the quotient term analysis. The preservice teacher questioned whether the term was an essential mathematical term and whether or not it should be changed. Adjusting mathematical terms requires that teachers understand issues of scope and sequence in mathematics given that the goal is mastery of the subject matter; it is complex (Nutta, Mokhtari, & Strebel, 2012). For example, if a preservice teacher does not understand the trajectory of mathematical content, then it is difficult to identify what is important and relevant in the current context. If the focus is on understanding whether or not students can build or comprehend a number's value, then exchang-

ing 6 for six (as explained in the results) should not be problematic. Of course, the eventual goal is for ELLs to be able to solve the problem regardless of how the numbers are presented.

The use of tools was not a specific component of our framework (Figure 1); however, the use of tools was discussed within the course. Several of the participants discussed the potential benefits of using tools within the context of helping ELLs. Specifically, the results showcased the perceived importance of tools as visual aids to support learning. While tools and visuals can benefit all, they are often advantageous to ELLs as tools help connect the language to an object (like connecting a meter stick with its actual length as one preservice teacher explained; Furner, Yahya, & Duffy, 2005; Garrison & Mora, 1999). Pictures and other graphical representations can also be used to demonstrate understanding (Chamot, 2009), and several preservice teachers adjusted their word problems using visualizations (e.g., providing drawings of corn). However, it is also important to note that while ELLs can benefit from tools and visuals, language demands should also be reduced while simultaneously developing English skills (Harper & de Jong, 2004). While the preservice teachers recognized the usefulness of tools and manipulatives, they were able to voice the need for other supportive adaptations.

The structural adaptations represented an understanding by preservice teachers of how the structural presentation of the problem impacted ELLs' ability to understand what was being asked of them mathematically. By visually breaking apart the word problem, it allowed the ELL to focus on the mathematical concepts as evidence by the preservice teacher who used a list of sentences rather than a paragraph. This type of adaptation also requires teachers to have a firm grasp of ELLs' language proficiency in order to anticipate structural difficulties (Echevarria & Graves, 2010). Rearranging how the numbers were presented in the word problem reflected one preservice teacher's understanding of how beginning ELLs may be translating from English to their native language word for word and how that may impact how the ELLs process the information. It is important to emphasize that the eventual goal is for all ELLs to have enough mastery of English and mathematical concepts to solve problems regardless of how they are presented on various standardized tests (Chamot, 2009). However, scaffolding word problems for ELLs in ways such as those discussed here can help ELLs on their way to that goal (Carr et al., 2009; Orosco et al., 2011).

Implications for Teacher Educators

By having preservice teachers engage in fieldwork with ELLs, they are able to see the "real-world" application of what they are learning in their coursework (Fitts & Gross, 2012; Mihai & Pappamihiel, 2012). Understanding ELLs is critical to better meeting their needs (Rhine, 1995) and encouraging ELLs to talk can support their development (Bielenberg & Fillmore, 2004/2005). The adaptation of cur-

riculum for ELLs is not an easy process; it takes time and practice (Hite & Evans, 2006; Orosco et al., 2011). It also requires collaboration between content area specialists and, in this case, mathematics education faculty and faculty with expertise working with ELLs (Nutta et al., 2012). Together, faculty can effectively design a framework that meets the needs of the preservice teachers as well as the ELLs they will serve. Furthermore, when preservice teachers see faculty collaborating, they can learn from that modeling for their own future collaboration with colleagues. The framework provided allowed preservice teachers to take a first step in learning how to adapt curriculum to better meet the needs of ELLs. Preservice teachers should be provided with an opportunity to learn about ELLs *from* ELLs; doing so puts the learning into a context that will support theory aligning with authentic practice (Mihai & Pappamihiel, 2012). Perhaps this structure will allow preservice teachers to gain experience that they will carry over into their careers as teachers. Further research needs to be conducted to investigate this idea as well as how other content areas can benefit from such a framework.

It is important to note that there were certain limitations to this study. First and foremost, the sample size is quite small and may not be representative of other preservice teachers (our study was mostly White women). Also, the structure of the framework seemed to confine the preservice teachers to Number and Operations problems. While there was no restriction to the types of problems selected, for some reason, most were from this content area. Because of the lack of mathematical diversity, this limitation can create issues in terms of truly understanding the adaptions. It seems that adaptions were more commonly implemented with Number and Operations, so measuring preservice teachers' changes in thinking is limited to word problems that focused on this content area. And finally, the emphasis on helping the ELL get the "right answer" rather than productive struggle with meaning was an issue. The preservice teachers seemed to measure success based on correctness of the problem and did not take the time to understand the student's thinking. Future implementation of this framework should include a discussion on the meaning of success in mathematics (see, e.g., Gillmor, Poggio, & Embretson, 2015; Kapur, 2014).

Concluding Thoughts

While preservice teachers are often in need of experiences working with ELLs, it is sometimes a neglected area of focus in education programs (Ernst-Slavit & Slavit, 2007; Freeman & Crawford 2008). The framework provided here (Figure 1) along with the analysis of preservice teachers implementation and reflection of adaptations demonstrate the complexities of teaching ELLs word problems. Additionally, the potential of guiding preservice teachers in this area is also demonstrated. This framework provides an opportunity for preservice teachers to learn from

ELLs while providing opportunities to put theory learned in courses into practice that can ultimately impact ELLs' opportunities to succeed in mathematics classes (Furner et al., 2005).

Adapting the text is a SEI technique that involves rewriting specific sections of a text containing critical concepts and information that remain intact in the process. Adapting the text and adjusting readability is time consuming and requires effort and thought (Walkington, Clinton, Ritter, & Nathan, 2015). But if we are serious about meeting the educational needs of this student population, the added time and effort involved in the process of adapting the material will be beneficial because mathematics material will become more accessible to ELLs.

References

Abedi, J. (2006). Language issues in item development. In S. M. Downing & T. M. Haladyna (Eds.). *Handbook of test development*. Mahwah, NJ: Erlbaum.

Abedi, J., Courtney, M., Leon, S., Kao, J., & Azzam, T. (2006). *English language learners and math achievement: A study of opportunity to learn and language accommodation.* (CRESST/CSE Tech. Rep. No. 702). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing.

Abedi, J., Hofstetter, C., Baker, E., & Lord, C. (2001). NAEP math performance and test accommodations: Interactions with student language background. (CSE Tech. Rep. No.536). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing.

Abedi, J., & Lord, C. (2001). The language factor in mathematics tests. *Applied Measurement in Education, 14*(3), 219–234.

Abedi, J., Lord, C., & Plummer, J. (1995). *Language background as a variable in NAEP mathematics performance: NAEP TRP Task 3D: Language background study*. Los Angeles: UCLA/ Center for the Study of Evaluation/National Center for Research on Evaluation, Standards, and Student Testing.

Adetula, L. (1990). Language factor: Does it affect children's performance on word problems? *Educational Studies in Mathematics, 21*(4), 351–365.

Arizona Department of Education. (2009). *AIMS Grade 4 Mathematics Sample Test and Think-Throughs.* Phoenix, AZ: Arizona Department of Education.

Avalos, M. A., Medina, E., & Secada, W. G. (2015). Planning for instruction: Increasing multilingual learners' access to algebraic word problems and visual graphics. In L. C. de Oliveira, A. Bright, & H. Hansen-Thomas (Eds.), *The Common Core State Standards in mathematics for English language learners: High school* (pp. 5–28). Alexandria, VA: TESOL.

Bielenberg, B., & Fillmore, L. (2004/2005). The English they need for the test. *Educational Leadership, 62*(4), 45–49.

Bunch, G. C. (2013). Pedagogical language knowledge preparing mainstream teachers for English learners in the new standards era. *Review of Research in Education, 37*(1), 298–341.

Carr, J., Carroll, C., Cremer, S., Gale, M., Lagunoff, R., & Sexton, U. (2009). *Making mathematics accessible to English learners: A guidebook for teachers*. San Francisco, CA: WestEd.

Celedón-Pattichis, S., & Ramirez, N. G. (Eds.). (2012). *Beyond good teaching: Advancing mathematics education for ELLs*. Reston, VA: National Council of Teachers of Mathematics.

Chamot, A. U. (2009). *The CALLA handbook: Implementing the cognitive academic language learning approach* (2nd ed.). White Plains, NY: Pearson Education/Longman.

Charles, R., Crown, W., & Fennell, F. (2004). *Arizona mathematics: Scott Foresman Addison Wesley*. New York, NY: Pearson.

Coady, M., Harper, C., & de Jong, E. (2011). From preservice to practice: Mainstream elementary teacher beliefs of preparation and efficacy with English language learners in the state of Florida. *Bilingual Research Journal, 34*(2), 223–239.

Darling-Hammond, L. (2010). Teacher education and the American future. *Journal of Teacher Education, 61*(1-2), 35–47.

de Jong, E., & Harper, C. (2005). Preparing mainstream teachers for English-language learners: Is being a good teacher good enough? *Teacher Education Quarterly, 32*(2), 101–124.

Durgunoglu, A. Y., & Hughes, T. (2010). How prepared are the U.S. preservice teachers to teach English language learners? *International Journal of Teaching and Learning in Higher Education, 22*(1), 32–41.

Dyck, N., & Pemberton, J. B. (2002). A model for making decisions about text adaptations. *Intervention in School and Clinic, 38*(1), 28–36.

Echevarria, J., & Graves, A. (2010). *Sheltered content instruction: Teaching students with diverse abilities* (4th ed.). Boston, MA: Allyn & Bacon.

Echevarria, J., Vogt, M., & Short, D. (2008). *Making content comprehensible for English learners: The SIOP Model*. Boston, MA: Pearson.

Ernst-Slavit, G., & Slavit, D. (2007). Educational reform, mathematics and diverse learners. *Multicultural Education, 14*(4), 20–27.

Feldon, D. F. (2007). Cognitive load and classroom teaching: The double-edged sword of automaticity. *Educational Psychologist, 42*(3), 123–137.

Fitts, S., & Gross, L. (2012). Teacher candidates learning from English learners: Constructing concepts of language and culture in Tuesday's tutors after-school program. *Teacher Education Quarterly, 39*(4), 75–95.

Freeman, B., & Crawford, L. (2008). Creating a middle school mathematics curriculum for English-language learners. *Remedial and Special Education, 29*(1), 9–19.

Furner, J., Yahya, N., & Duffy, M. (2005). Teach mathematics: Strategies to reach all students. *Intervention and School Clinic, 41*(1), 16–23.

García, E., Arias, M. B., Murri, N. J. H., & Serna, C. (2010). Developing responsive teachers: A challenge for a demographic reality. *Journal of Teacher Education, 61*(1-2), 132–142.

Garrison, L., & Mora, J. K. (1999). Adapting mathematics instruction for English language learners: The language-concept connection. In L. Ortiz-Franco, N. Hernández, & Y. De la Cruz (Eds.), *Changing the face of mathematics: Perspectives on Latinos* (pp. 35–48). Reston, VA: National Council of Teachers of Mathematics.

Gathercole, S. E., & Baddeley, A. D. (1993). *Working memory and language*. Hillsdale, NJ: Erlbaum.

Gibbons, P. (2002). *Scaffolding language, scaffolding learning: Teaching second language learners in the mainstream classroom*. Portsmouth, NH: Heinemann.

Gillmor, S. C., Poggio, J., & Embretson, S. (2015). Effects of reducing the cognitive load of mathematics test items on student performance. *Numeracy, 8*(1), 1–18.

Goldenberg, C. (2013). Unlocking the research on English learners: What we know—and don't yet know—about effective instruction. *American Educator, 37*(2), 4–11.

Gómez, C. L., Kurz, T. L., & Jimenez-Silva, M. (2011). Your inner English teacher. *Mathematics Teaching in the Middle School, 17*(4), 238–243.

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice, 15*(2), 273–289.

Guo, Q., & Koretz, D. (2013). Estimating the impact of the Massachusetts English Immersion Law on limited English proficient students' reading achievement. *Educational Policy, 27*(1), 121–149.

Haag, N., Heppt, B., Stanat, P., Kuhl, P., & Pant, H. A. (2013). Second language learners' performance in mathematics: Disentangling the effects of academic language features. *Learning and Instruction*, *28*, 24–34.

Harper, C., & de Jong, E. (2004). Misconceptions about teaching English-language learners. *Journal of Adolescent & Adult Literacy*, *48*(2), 152–162.

Hite, C., & Evans, L. (2006). Mainstream first-grader teachers' understanding of strategies for accommodating the needs of English language learners. *Teacher Education Quarterly*, *33*(2), 89–110.

Janzen, J. (2008). Teaching English language learners in content areas. *Review of Educational Research*, *78*(4), 1010–1038.

Kapur, M. (2014). Productive failure in learning math. *Cognitive Science*, *38*(5), 1008–1022.

Keengwe, J. (2010). Fostering cross-cultural competence in preservice teachers through multicultural education experiences. *Early Childhood Education Journal*, *38*(3), 197–204.

Kyrene School District. (2009). First grade practice problems. Unpublished.

LeCompte, M. (2000). Analyzing qualitative data. *Theory Into Practice*, *39*(3), 146–154.

Lepik, M. (1990). Algebraic word problems: Role of linguistic and structural variables. *Educational Studies in Mathematics*, *21*(1), 83–90.

López, F., Scanlan, M., & Gundrum, B. (2013). Preparing teachers of English language learners: Empirical evidence and policy implications. *Education Policy Analysis Archives*, *21*(20), 1–35.

Lucas, T. (Ed.). (2011). *Teacher preparation for linguistically diverse classrooms: A resource for teacher educators*. NY: Routledge.

Martinello, M. (2008). Language and the performance of English-language learners in math word problems. *Harvard Educational Review*, *78*(2), 333–368.

Menken, K. (2013). Restrictive language education policies and emergent bilingual youth: A perfect storm with imperfect outcomes. *Theory Into Practice*, *52*(3), 160–168.

Menken, K., & Solorza, C. (2014). No child left bilingual accountability and the elimination of bilingual education programs in New York City schools. *Educational Policy*, *28*(1), 96–125.

Mihai, F. M., & Pappamihiel, N. E. (2012). Strengthening the curriculum by adding EL-specific coursework and related field experiences. In J. Nutta, K. Mokhtari, & C. Strebel (Eds.), *Preparing every teacher to reach English learners: A practical guide for teacher educators*. Cambridge, MA: Harvard Education Press.

Moschkovich, J. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning*, *4*(2&3), 189–212.

Moschkovich, J. (2007). Using two languages when learning mathematics. *Educational Studies in Mathematics*, *64*(2), 121–144.

Moschkovich, J. (2010). Language and learning mathematics: Resources, challenges, and issues for research. In J. Moschkovich (Ed.), *Language and mathematics education: Multiple perspectives and directions for research* (pp. 1–28). Charlotte, NC: Information Age.

Moschkovich, J. (2013). Principles and guidelines for equitable mathematics teaching practices and materials for English language learners. *Journal of Urban Mathematics Education*, *6*(1), 45–57. Retrieved from http://ed-osprey.gsu.edu/ojs/index.php/JUME/article/view/204/135

Nutta, J. W., Mokhtari, K., & Strebel, C. (2012). *Preparing every teacher to reach English learners: A practical guide for teacher educators*. Cambridge, MA: Harvard Education Press.

O'Halloran, K. (2008). *Mathematical discourse: Language, symbolism and visual images*. New York, NY: Continuum.

Orosco, M., Swanson, H., O'Connor, R., & Lussier, C. (2011). The effects of dynamic strategic math on English language learners' word problem solving. *The Journal of Special Education*, *47*(2), 96–107.

Parra, E. B., Evans, C. A., Fletcher, T., & Combs, M. C. (2015). The psychological impact of English language immersion on elementary age English language learners. *Journal of Multilingual Education Research*, *5*(1), 33–65.

Rhine, S. (1995). The challenge of effectively preparing teachers of limited-English-proficient students. *Journal of Teacher Education*, *46*(5), 381–389.

Rolstad, K., Mahoney, K., & Glass, G. (2005). The big picture: A meta-analysis of program effectiveness research on English language learners. *Educational Policy*, *19*(4), 572–594.

Samson, J., & Collins, B. A. (2012). *Preparing all teachers to meet the needs of English language learners*. Washington, DC: Center for American Progress.

Santos, M., Darling-Hammond, L., & Cheuk, T. (2012). *Teacher development to support English language learners in the context of Common Core State Standards*. Understanding Language Conference, Stanford University, California. Retrieved from http://ell.stanford.edu/sites/default/files/pdf/academic-papers/10-Santos%20LDH%20Teacher%20Development%20FINAL.pdf

Sato, E. (2008). *Linguistic modification: Part II—A guide to linguistic modification: Increasing English language learner access to academic content.* Washington, DC: LEP Partnership.

Schnotz, W., & Kürschner, C. (2007). A reconsideration of cognitive load theory. *Educational Psychology Review*, *19*(4), 469–508.

Simpson, A., & Cole, M. W. (2015). More than words: A literature review of language of mathematics research. *Educational Review*, *67*(3), 1–16.

Siwatu, K. O. (2011). Preservice teachers' sense of preparedness and self-efficacy to teach in America's urban and suburban schools: Does context matter? *Teaching and Teacher Education*, *27*(2), 357–365.

Swanson, H. L. (2015). Cognitive strategy interventions improve word problem solving and working memory in children with math disabilities. *Frontiers in Psychology*, *6*(1099), 1–13. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4523823/pdf/fpsyg-06-01099.pdf

Swanson, H. L., Moran, A. S., Bocian, K., Lussier, C., & Zheng, X. (2013). Generative strategies, working memory, and word problem solving accuracy in children at risk for math disabilities. *Learning Disability Quarterly*, *36*(4), 203–214.

Thurlow, M. L., & Kopriva, R. J. (2015). Advancing accessibility and accommodations in content assessments for students with disabilities and English learners. *Review of Research in Education*, *39*(1), 331–369.

Truxaw, M. P., & Rojas, E. D. (2014). Challenges and affordances of learning mathematics in a second language. *Journal of Urban Mathematics Education*, *7*(2). 21–30. Retrieved from http://ed-osprey.gsu.edu/ojs/index.php/JUME/article/view/233/160

van Ingen, S., & Ariew, S. (2015). Making the invisible visible: Preparing preservice teachers for first steps in linking research to practice. *Teaching and Teacher Education*, *51*, 182–190.

Walkington, C., Clinton, V., Ritter, S. N., & Nathan, M. J. (2015). How readability and topic incidence relate to performance on mathematics story problems in computer-based curricula. *Journal of Educational Psychology*, *107*(4), 1051–1074.

Webster, N. L., & Valeo, A. (2011). Teacher preparedness for a changing demographic of language learners. *TESL Canada Journal*, *28*(2), 105–128.

Wright, W. (2010). *Foundations for teaching English language learner: Research, theory, policy, and practice*. Philadelphia, PA: Caslon.

Yeong, J., & Chang, H. (2014). Teaching mathematics for Korean language learners based on ELL education models. *ZDM Mathematics Education*, *46*(6), 939–951.