Embedded Instructional Supports in Math Content
Barbara Freeman and Lindy Crawford

Introduction

To be academically successful in school, English language learners (ELLs) students must not only learn a new language and integrate with a different culture, but must *concurrently* learn and master a range of academic content including mathematics and science in that new, non-native language. Navigating through a single day in a different country, leave alone acquiring proficiency in a new task using a foreign language, is a difficult and exhausting undertaking for the most confident and accomplished person. For a young student confronted with this experience on a daily basis, it frequently proves insurmountable. According to the 2005 *Nation's Report Card*, 85 percent of Hispanic 8th grade students are performing below proficient in math (45 percent of whom are below basic). By 12th grade, 92 percent of Hispanic students are failing to reach proficiency in math, representing more than a 20 percent gap with their White peers; a gap which has persisted and has shown no significant change since 1992 (National Center for Education Statistics, 2007). The Help with English Language Proficiency (HELP) Math program was created specifically to support ELLs from third grade through high school as they overcome this formidable challenge. HELP scaffolds (Vygotsky, 1978; Wood, Bruner, & Ross, 1976; Bruner, 1975) student learning by embedding research-based sheltered instruction techniques and Sheltered Instruction Observation Protocol (Short & Echevarria, 1999; SIOP) principles directly into the web-based curriculum.

Language Proficiency and Prerequisite Knowledge

Although it is widely accepted that mathematics is a universal language, a student is taught the subject through the use of language, and must quickly overcome daunting language barriers in order to keep up with what is being taught in class. When students acquire a social grasp of the language (basic interpersonal communications), it is easy to make the assumption that they are a long way down the road toward comprehension, when in fact they may have barely started their academic journey. To understand content and develop mathematical skills and reasoning—long before comprehension can occur at a symbolic level—a student needs to be able to read, problem-solve and communicate using technical and academic English (American Educational Research Association, 2004). Academic English is a specialized language used in the context of the classroom, textbook, and standardized assessment. Numerous studies show that it takes anywhere between four and seven years to attain cognitive academic language proficiency (Cummins, 1981; Collier, 1987; Collier & Thomas, 1989). Yet, despite this, it is compulsory under the *No Child Left Behind* (*NCLB*) Act of 2002 that ELL students meet the same state academic achievement standards as native English speakers at the same grade level – in the same time frame.

Reading research shows vocabulary knowledge to be one of the most significant factors affecting students' success (Blachowicz, & Cobbs, 2007). Like reading, we now understand that a "vocabulary gap" (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2006) is equally problematic for math learning. For example, many math terms are technical and new to learners (e.g., *coefficient, tessellation*), as are the symbols (>*greater than*, ∑ *summation*); others are misleadingly familiar (e.g., *scale, value*). Math content is typically taught and tested using grammatical constructions such as *which of the following* or *simplify the equation*, and cause and effect language such as *if not x, then y*. Such constructions are problematic not only because of the linguistic impediments which may arise, but also because of the culture-specific aspects of mathematical language. If a student cannot understand what is being said in math class, they tend to "switch off", making it difficult to move beyond the language obstacle to master math content and skills – no matter how mathematically able the student may actually be (Freeman & Crawford, 2008).

Students who have gaps in their fundamental understanding of underlying principles (Bruner, 1960), missing background knowledge (Dale, 1969), and/or prior concept knowledge and pre-requisite skills (Marzano, 2004; Dochy, Segers, & Buehl, 1999) find it particularly difficult to learn math in a non-native language. This is especially critical in the field of math in which the content builds and spirals year on year and "pre-requisite skills serve as anchors for math ideas" (Sharma, 1989, p.4). For example, students may exhibit gaps in their declarative knowledge and skills (calculating, measuring, arithmetic facts), foundational conceptual knowledge (parts-to-whole, number relationships), procedural knowledge (algorithms, operations, formulas), and problem solving abilities (combining facts and concepts).

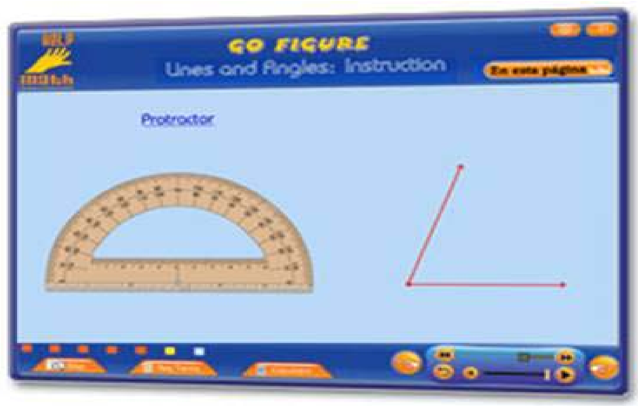
For the student who is numerate and literate in their native language, simple translation of the math instruction into the learner's native language, or time to acquire the new language, is most of what they require. For the great majority of students learning math in a non-native language (the more than 85 percent failing to reach math proficiency in secondary school), this is not the case. Students lacking knowledge of foundational math concepts, academic literacy skills and/or the relevant vocabulary necessary to understand math at grade-level find themselves at a severe disadvantage and thus mere translation of content offers them very little.

Embedded Support

HELP embeds specific instructional supports directly into the digital math content to scaffold student learning. We view this as instrumentally important for ELLs as adding Braille to books for the blind. Braille will not automatically make blind students literate; however, it will provide them with a genuine opportunity to read and learn. Likewise, entrenching language and prior math knowledge scaffolds into the content will not automatically make ELLs numerate, but it will give them a fair chance to learn math. The value of a resource cannot be viewed in isolation from the individual's capability to use that resource (Sen, 1992).

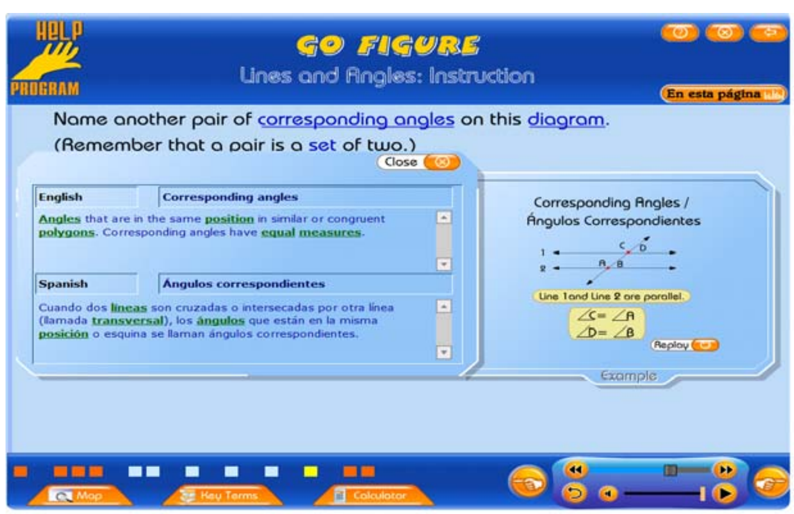
HELP uses sheltered instruction techniques and SIOP principles delivered through technology to make math comprehensible. HELP content is broken-down into small manageable learning chunks (Miller, 1956), with guided practice to develop math facts, skills, concepts and problem-solving. Screens are ‘clean’ with few distracters, enabling students to maintain focus as they continually interact with manipulatives, games, and real-world scenarios. As shown in Figure 1, for example, HELP adds extra-linguistic cues (Krashen, 1992) by synchronizing audio, visual, and text to create a visual connection between words and meaning (e.g., corresponding vocabulary, symbols or pictures flash in sync with audio). Spanish translation is available on every page for the student who requires extra support in their home language.

Figure 1. **Software providing visual support**



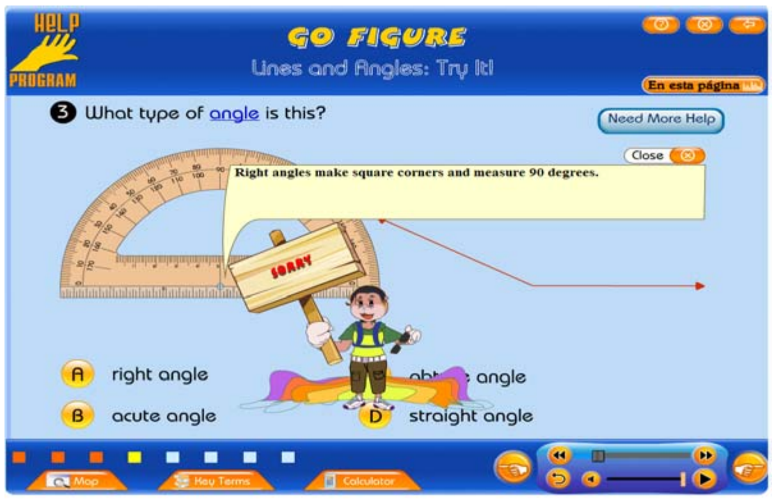
HELP explicitly teaches technical vocabulary and academic English including a bilingual, pictorial dictionary with contextual hyperlinks on every page (Fig. 2).

Figure 2. **Contextual support of Vocabulary**



Providing massed practice and cumulative and judicious review (Heward, 2009; Fuchs et al., 2008) is essential to the learning process, particularly for students who are missing prerequisite skills or with special needs. Figure 3 shows how feedback loops and hints are embedded into the software, providing interactive practice, unobtrusive assessment, and consistent review.

Figure 3. **Software with massed practice and review**



Conclusion

It is imperative that math interventions are targeted and meaningful to special populations. Current technology enables us to embed instructional supports directly into the academic math content in order to eliminate language barriers and methodically address gaps in vocabulary, as well as prior math knowledge and skills — well understood needs of ELL students. HELP Math and other specifically developed ELL resources provide students with a genuine opportunity to learn and achieve in math.

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Barbara Freeman, MBA, is a doctoral student of educational leadership and change at Fielding Graduate University and chief operating officer of Digital Directions International. She is the creator of the Help with English Language Proficiency (HELP) Math program. It is from her initial research that the HELP program was developed.

Lindy Crawford, Ph.D., is an Associate Professor of Special Education and Associate Dean of Education at the University of Colorado at Colorado Springs. Her research interests include meaningful inclusion of students with disabilities in statewide test programs and effective curriculum and instruction for English-language learners.