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Hispanic dual language learning kindergarten students' response to a numeracy intervention: A randomized control trial

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ABSTRACT

This study evaluated the impact of the Spanish version of the Building Blocks software program and vocabulary on kindergarten mathematics outcomes. Participants included 270 Hispanic dual language learners from low-income communities. Relative to children in the computer assisted instruction (CAI) literacy control group, those in the Building Blocks CAI group evidenced higher posttest scores for Spanish mathematics, but not for English mathematics, after controlling for pretest numeracy. There were also main effects of English vocabulary and Spanish vocabulary predicting posttest mathematics scores in English and Spanish, after controlling for covariates. These findings support the use of the Building Blocks software as a supplemental method for improving the mathematics competencies of Hispanic dual language learners from low-income backgrounds.

1. Introduction

Relative to non-Hispanic White peers, Hispanic students in the U.S. have underperformed in mathematics for decades (Clements & Sarama, 2011; Denton & West, 2002; National Center for Educational Statistics, 2015; Natriello, McDill, & Pallas, 1990). Hispanic students are at increased risk for low academic achievement due to high rates of poverty (Lopez & Velasco, 2011) and lower rates of preschool enrollment (Barnett, Carolan, & Fitzgerald, & Squires, 2011; Figueras-Daniel & Barnett, 2013; Kena et al., 2016) than peers from similar economic backgrounds. Some also argue that low levels of English language proficiency among Hispanic children learning Spanish and English (i.e., Hispanic dual language learners) is at least partially responsible for these children's low rates of 'academic success' in the U.S. (Galindo, 2010). Given the experiential gaps to acquire English proficiency and that 'academic success' in the U.S. will probably continue to be defined as achievement on standardized tests administered in English despite the growing embracement of dual language instruction in some states, there is a pressing need to identify mathematics programs that promote mathematics competencies in Spanish and English among Hispanic dual language learners (DLLs). Therefore, the present study examines the impact of a numeracy intervention when used with Hispanic DLLs and considers the effect of vocabulary on kindergarten mathematics outcomes.

2. Relations between language and mathematics

Language is the medium of classroom instruction and is thought by some to be the means by which young children refine their understanding of numbers (Purpura, Napoli, Wehrspann, & Gold, 2016; Spelke, 2003). Indeed, empirical study has demonstrated that scores of English language at school entry are predictive of growth in scores on English mathematics tests through ninth grade (Duncan et al., 2007; Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010; Purpura, Hume, Sims, & Lonigan, 2011; Romano, Babchishin, Pagani, & Kohen, 2010). However, few studies that consider the prediction of kindergarten mathematics outcomes from language scores at school entry include Hispanic DLLs. For example, Kleemans, Segers, and Verhoeven (2011) demonstrated that second

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language (L2) phonological awareness and grammatical ability were associated with concurrently measured L2 logical operations skills and numeracy skills in a sample of bilingual Turkish and Moroccan (students' first language – L1) speaking kindergarten students learning Dutch (students' L2). In a study of Canadian students, Romano et al. (2010) demonstrated that English vocabulary in kindergarten predicted third grade English mathematics achievement for students whose L1 was French. These studies suggest that L2 language competence is important to L2 mathematics outcomes in bilingual and DLL students. One would therefore expect English language proficiency at school entry to be predictive of English mathematics outcomes at the end of kindergarten for Hispanic DLLs in the U.S. However, the extent that this relation is a matter of linguistic formatting of test items is not completely clear (see Abedi & Lord, 2001; Rhodes, Branum-Martin, Morris, Romski, & Sevcik, 2015).

2.1. Kindergarten numeracy

Kindergarten number competencies (i.e., understanding of number concepts and number relations; referred to as numeracy throughout this manuscript) are important to children's growth in mathematics achievement (Jordan, Kaplan, Ramineni, & Locuniak, 2009) and are predictive of mathematics learning disability (Mazzacco & Thompson, 2005). Early numeracy also provides a foundation for later academic achievement (Duncan et al., 2007), predicting children's reading achievement better than early literacy skills (Duncan & Magnuson, 2011; Duncan et al., 2007; Koponen, Salmi, Eklund, & Aro, 2013) and predicting mathematics achievement through 15 years of age (Watts, Duncan, Siegler, & Davis-Kean, 2014). Finally, mastery of numeracy concepts allows for stronger understanding of more complex mathematical problems such as applied problem solving (Foster, Anthony, Clements, & Sarama, 2015; Foster, Anthony, Clements, Sarama, & Williams, 2016) and problem solving within the areas of measurement, data analysis, and geometry (National Research Council, 2009).

2.2. Kindergarten mathematics programs

High-quality mathematics instruction helps increase mathematics achievement and helps prevent or mitigate mathematics learning difficulties (Clements & Sarama, 2011; Cross, Woods, & Schweingruber, 2009; Foster et al., 2016; Magnuson, Meyers, Ruhm, & Waldfogel, 2004). Moreover, benefits derived from high-quality mathematics instruction provided during the preschool to early elementary school period appear greatest for children from low-income families and children whose parents have little education (Case, Griffin, & Kelly, 1999; Clements, Sarama, Spitler, Lang, & Wolfe, 2011; Griffin & Case, 1997; National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2011; Peisner-Feinberg et al., 2001; Shonkoff & Phillips, 2000). However, most mathematics instruction in kindergarten is inadequate, "teaching" children what they already know (Engel, Claessens, & Finch, 2013). A more useful framework for mathematics instruction would involve targeting fundamental learning goals (e.g., subitizing, counting and arithmetic using subitizing and counting), adjusting instruction according to individual children's progress along learning trajectories, and teaching each fundamental skill to the level of mastery (Clements & Sarama, 2014; National Research Council, 2009; Sarama & Clements, 2009).

Because Hispanic children in the U.S. are less likely than peers to attend preschool (Barnett et al., 2011), kindergarten is a critical period in these children's lives for acquiring mathematical competencies. However, few studies have evaluated the effectiveness of mathematics programs for Hispanic DLLs in the U.S. (Cross et al., 2009). A noteworthy exception was Wang and Woodworth's (2011) evaluation of DreamBox Learning, an online mathematics computer program that supplements face-to-face mathematics instruction. Of the 583 kindergarten and first-grade students in Wang and Woodworth (2011), 87.3% were classified as Hispanic and 80.6% were classified as English learners. The results indicated that children who received supplemental instruction with DreamBox Learning outperformed comparison students who only received face-to-face mathematics instruction on a broad test of mathematics achievement and on a test of measurement and geometry achievement at the end of the school year. These results are promising, suggesting that supplemental computer-based mathematics instruction can improve early mathematical competencies among young Hispanic DLLs.

2.3. Computer-assisted instruction

In the present study, *computer-assisted instruction* (CAI) in mathematics refers to educational software programs that help students learn and apply mathematical concepts and skills (Harskamp, 2014). CAI is most often used as a supplement to teacher-directed classroom instruction (Slavin & Lake, 2008). Advantages of CAI include ease of implementation, standardized scope and sequence of curriculum, and suitability for individualized instruction through regular monitoring of children's progress coupled with adaptive instruction (Anthony, 2016; Clements & Sarama, 2018; Citation Blinded for Review). However, educators' questions and reasonable concerns about developmental appropriateness, logistics of implementation, compatibility with core curricula, and effectiveness interferes with widespread use of CAI during the early school years (Clements & Sarama, 2003; Cuban, 2001).

Reviews of the scientific literature generally conclude that CAI can provide substantial benefits for children's learning of mathematics (Baroody, Eiland, Purpura, & Reid, 2013; Sarama, 2010, 2018; Cross et al., 2009; Lentz, Seo, & Grunner, 2014; Li & Ma, 2010; Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009; Slavin & Lake, 2008). One review by the National Mathematics Advisory Panel (2008) indicated that CAI applications that are well designed and well implemented can have a positive effect on mathematics performance, and empirical study supports this conclusion (Harskamp, 2014; Moradmand, Datta, & Oakley, 2013; Nusir, Alsmadi, Al-Kabi, & Sharadgah, 2013). A more recent meta-analysis of rigorous studies similarly concludes that there are positive effects of CAI in mathematics when used as a supplement to children's daily classroom instruction (Cheung & Slavin, 2013). Similarly, another meta-analysis of studies examining the use of CAI for early mathematics found a moderate effect size (Harskamp, 2014), whereas still another meta-analysis found positive effects for the use of technological manipulatives with children in preschool and kindergarten (Moyer-Packenham & Westenskow, 2013). Therefore, CAI represents a viable medium to deliver supplemental mathematics instruction.

2.4. Building Blocks mathematics program

The complete Building Blocks (BB) pre-K mathematics program is a comprehensive curriculum that includes a teachers' edition, assessment and resource guides, manipulatives, and a software suite (Clements & Sarama, 2013). The classroom curriculum and software are designed to develop understanding and skill fluency in the domains of numeracy and geometry. A series of empirical studies have supported the effectiveness of the BB program when all its components have been implemented together for use with preschool age children from low-income backgrounds (e.g., Sarama, 2007, 2008; Clements et al., 2011). However, less is known about the effectiveness of the software that accompanies the BB pre-K mathematics program.