Digital Tools in Mathematics Education and DLLs: Evidence from a Randomized Control

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The Context of the Challenge

- Early math achievement is critical to academic trajectories (e.g., Duncan et al., 2007)
- Hispanic students underperform relative to majority peers
  - 74% of Hispanic K-12 students are not proficient in mathematics vs 49% of majority peers (NCES, 2015)
- Few math interventions proven effective for Hispanic students, especially Dual Language Learners (DLLs) (Cross et al., 2009)
- Hispanic students are the fastest growing segment of the U.S. population (29% of the U.S. K-12 public school system) (Kena et al., 2016)

Risk Factors for Low Academic Achievement

- High rates of poverty (Lopez & Velasco, 2011)
- Lower rates of preschool enrollment (e.g., Kena et al., 2016)
- Low levels of English proficiency (Galindo et al., 2010)
- Academic success often defined as achievement on English tests

Computer Assisted Instruction

Advantages (Anthony, 2016)

- Ease of implementation
- Standardized scope and sequence
- Suitability for individualized instruction
- Adaptive instruction
- Effective for Hispanic DLLs in kindergarten and first grade (Wang & Woodworth, 2001)

Concerns (Clements & Sarama, 2003; Cuban, 2001)

- Appropriateness
- Implementation logistics
- Compatibility with core curriculum
- Focus on basic skills (Kitchen & Berk, 2016)

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Evaluation of the Building Blocks Software

Current Study

Building Blocks Software

- Based on a comprehensive Curriculum Research Framework (Clements & Sarama, 2007; Clements, 2007) that includes a model for developing scientifically based software (Clements & Battista, 2000)
- 200+ activities & available in English and Spanish
  - Targets numeracy
    - Counting, comparing & ordering numbers, subitizing, composing numbers, adding & subtracting, multiplying & dividing
  - Targets geometry
    - Classifying, measuring, recognizing, composing, and comparing shapes, spatial sense & motions, & patterning
- Adaptive management system
  - Adjusts & differentiates instruction
  - Teaches skills to mastery

Effectiveness of the Software

- English version of the Building Blocks numeracy activities led to positive impacts on monolingual English speakers kindergarten outcomes (Foster, Anthony, Clements, Sarama, & Williams, 2016)
- 247 kindergartners from 37 classrooms in 9 schools
- Randomly assigned to computer assisted instruction condition
  - Building Blocks – math
  - Earobics Step 1 – phonological awareness
- Results
  - *Numeracy*: Building Blocks group outperformed Earobics group $F(1, 178) = 8.08$, $p < .01$; effect size = 0.43
  - *Applied Problems*: Building Blocks group outperformed Earobics group $F(1, 176) = 5.90$, $p = .02$; effect size = 0.37 (or 3.61 standard score units)

Research Aims

1. Examine effectiveness of Spanish version of Building Blocks software activities for numeric and quantitative understandings

2. Examine predictive value of vocabulary on posttest math outcomes

We expected Building Blocks software to benefit all children, but to be particularly beneficial for those with relatively high vocabulary.

Dual Language Data Collection Plan

Variables (Measure)	Pretest	Midpoint	Posttest
English Numeracy (REMA)	X		X
Spanish Numeracy (REMA-SPAN)	X		X
English Vocabulary (EOWPVT)		X	
Spanish Vocabulary (EOWPVT-SBED)		X	
Applied Problems (WJ-III)			X
Problemas Aplicados (Batería III)			X

Note. English and Spanish math tests were administered at pretest and posttest, unless the child failed a language screen. REMA is Research Based Early Maths Assessment; EOWPVT is Expressive One Word Picture Vocabulary Test; SPAN is Spanish; SBED is Spanish Bilingual Edition.

Prediction of *Spanish* Mathematics at Posttest

	Numeracy						Problemas Aplicados					
Variable	*β*	*SE*	*p*	R^2	*ES*	ΔR^2	*β*	*SE*	*p*	R^2	*ES*	ΔR^2
Model 1				.42						.44		
Autoregressor	.64	.04	<.001				.66	.04	<.001			
Group	.09	.04	.04		.26		.11	.04	< .01		.31	
Model 2				.41		-.01				.44		.00
Autoregressor	.64	.04	<.001				.68	.04	<.001			
Group	.09	.04	.05				.11	.04	.02			
English Vocabulary	-.03	.06	.62				-.13†	.05†	.01†			
Model 3				.50		.08				.55		.11
Autoregressor	.49	.06	<.001				.46	.05	<.001			
Group	.08	.04	.03				.10	.04	.01			
Spanish Vocabulary	.32	.07	<.001				.39	.05	< 001			

Note. Completely standardized results reported. [a]Autoregressor was Spanish numeracy at pretest.
† indicates suppression and should not be interpreted.

Prediction of *English* Mathematics at Posttest

	Numeracy					Applied Problems				
Variable	*β*	*SE*	*p*	R^2	ΔR^2	*β*	*SE*	*p*	R^2	ΔR^2
Model 1				.45					.50	
Autoregressor	.66	.05	<.001			.71	.05	<.001		
Group	.06	.05	.23			-.05	.04	.22		
Model 2				.45	.00				.52	.02
Autoregressor	.63	.06	<.001			.61	.07	<.001		
Group	.05	.04	.21			-.05	.04	.23		
English Vocabulary	.07	.06	.28			.18	.07	.01		
Model 3				.46	.01				.48	.00
Autoregressor	.61	.06	<.001			.70	.05	<.001		
Group	.05	.05	.26			-.06	.04	.18		
Spanish Vocabulary	.17	.06	<.01			-.03	.07	.64		

Note. Completely standardized results reported. [a]Autoregressor was English numeracy at pretest.

Discussion

- Spanish version of *Building Blocks* software led to reliable improvements
- Effect sizes (Spanish: numeracy = .26; applied problems = .31)
  - Exceed WWC threshold of .25
  - Represent learning over above that due to classroom instruction & maturation

- Vocabulary (i.e., proxy for language)
  - Is involved in solving math problems (e.g., Praet et al., 2013)
  - Medium used to connect quantitative knowledge to words and symbols (Purpura et al., 2011)
  - Related to development of math knowledge & integration of that knowledge with prior learning (Purpura and Ganley, 2014)

Conclusion & Future Directions

- Use of Building Blocks as a supplemental math program for Hispanic DLLs in kindergartners supported
- Adaptive computer software programs such as Building Blocks software may be help decrease risk for school failure

- Evaluate the English version of *Building Blocks* software & evaluate variations in instructional sequences that employ mixed use of English and Spanish versions