Does improved vocabulary enhance Hispanic English learners response to mathematics intervention?

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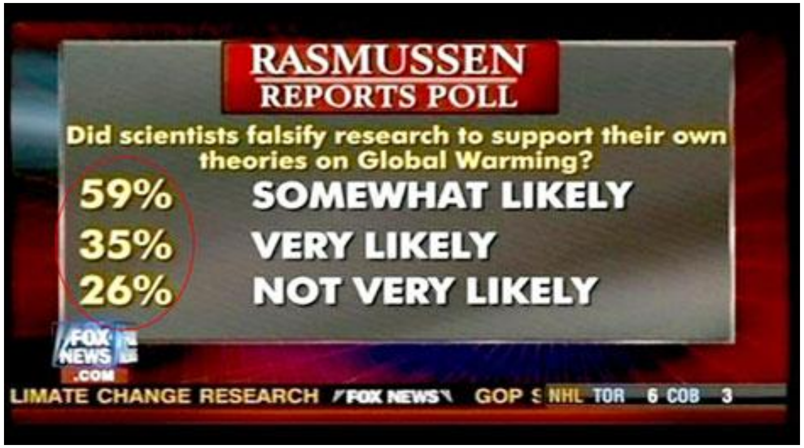
USF
UNIVERSITY OF SOUTH FLORIDA

Funding sources

INSTITUTE OF EDUCATION SCIENCES

- NCER Award Number: R305A080196 (PI-Jason Anthony)
- NCSER Award Number: R324B110007 (PI-Marcia Barnes)

Understanding of Mathematics?



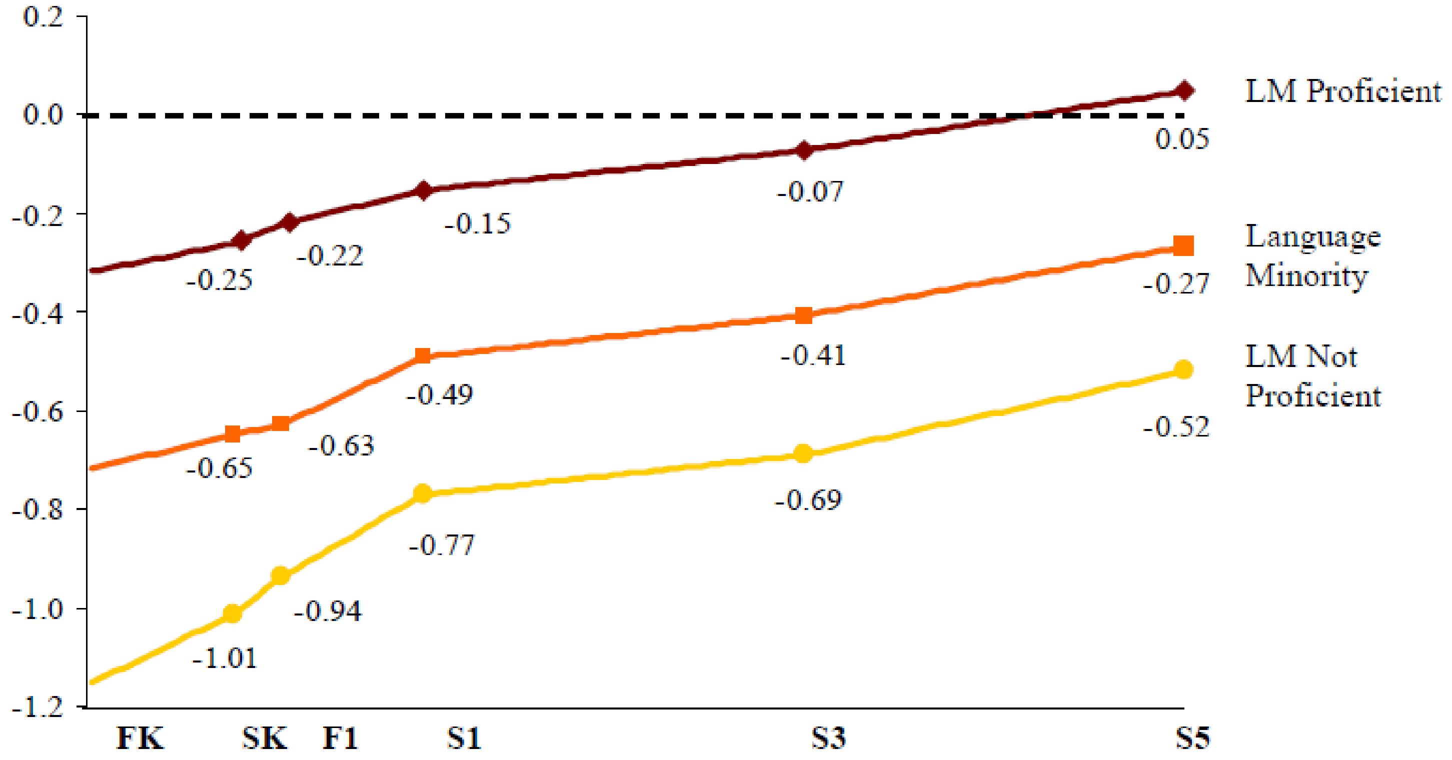
The Context of the Challenge

- 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)
- Hispanic students are the fastest growing segment of the U.S. population (29% of the U.S. public school system) (Kena et al., 2016)
- Few math interventions proven effective for Hispanic students, especially English learners (ELs) (Cross et al., 2009)

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

ECLS-Kindergarten Class of 1998-1999
Math Achievement Trend by Language Proficiency at kindergarten Entry (Galindo, 2009)



Note: Native-English speaking students are the reference group, represented by the value of “0” on the “Y” axes. Gaps measured in pooled standard deviation units.

Relationship between Language and Mathematics

- Language is the medium of classroom instruction
- Language is the means by which children refine their understandings of numbers (Spelke, 2003; Purpura et al., 2016)
- Language at school entry is predictive of growth in scores on English math tests through ninth grade (Duncan et al., 2007; Hooper et al., 2010)
- Few studies have considered the impact of language on math outcomes within the context of an intervention study for ELs in the U.S.

Computer Assisted Instruction (CAI)

Intervening During Kindergarten

High Quality Math Instruction

- Benefits
  - Increase mathematics achievement
  - Improve academic outcomes
  - Prevent mathematics learning difficulties (e.g., Cross, Woods, & Schweingruber, 2009)
- Greatest for children from low-income backgrounds & whose parents have little education (e.g., NAS, NAE, & IOM, 2011)
  - Lack opportunities to learn mathematics (Clements & Sarama, 2009)
  - Most kindergarten math programs are inadequate (Engel, Claessens, & Finch, 2013)
- Framework: (a) targeting fundamental goals, (b) adjusting & differentiating instruction, and (c) teaching to mastery

Kindergarten Numeracy

- Numeracy refers to understanding number concepts and number relations
  - Important to children's growth in math achievement (Jordan et al., 2009)
  - Predictive of mathematics learning disability (Mazzacco & Thompson, 2005)
  - Provides foundation for later academic achievement, predicting children's reading achievement better than early literacy skills (Duncan & Magnuson, 2011; Duncan et al., 2007; Koponen et al., 2013)
  - Allows for stronger understanding of more complex math problems (Foster et al., 2015; 2016) & solving measurement, data analysis, and geometry problems (NRC, 2009)

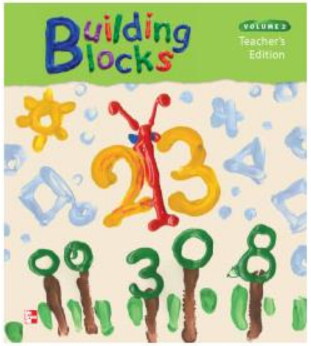
Computer Assisted Instruction

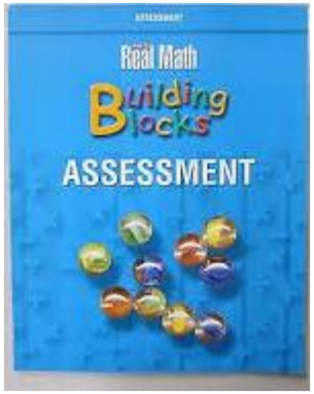
- Research demonstrates that high-quality, research-based technology is appropriate for, and benefits young children (e.g., Li, Atkins, & Stanton, 2006; Navarro et al., 2012), especially, minority children (Foster et al., 2016; Judge, 2005)
  - Evaluation of Dreambox Learning (Wang & Woodworth, 2011)
    - 583 kindergarten and first grade students
      - 87.3% Hispanic
      - 80.6% ELLs
  - Significant positive impact on tests of:
    - Broad mathematics
    - Measurement and geometry
- Computer-based math instruction is viable delivery model

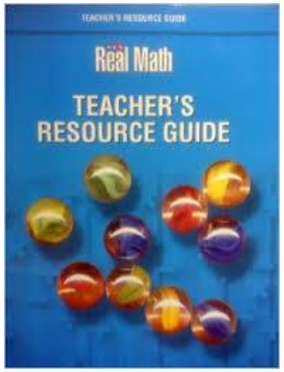
Building Blocks Math Program

Building Blocks Math Program

- Includes a teacher's edition, assessment & teacher resource guides, manipulatives, & software suite
- Designed to develop fluency in numeracy and geometry skills
- Series of studies have supported the effectiveness of the full program (e.g., Clements & Sarama, 2007; 2008; Clements et al., 2011)







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)
  - 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 Building Blocks Software

- English version of the 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 supported Building Blocks
    - *Numeracy*: $F(1, 178) = 8.08$, $p < .01$; **effect size = 0.43**
    - *Applied Problems*: $F(1, 176) = 5.90$, $p = .02$; **effect size = 0.37 (or 3.61 standard score units)**

Present Study

Research Aims

1. Examine effectiveness of Spanish version of Building Blocks software numeracy activities

2. Examine predictive value of vocabulary on posttest math outcomes

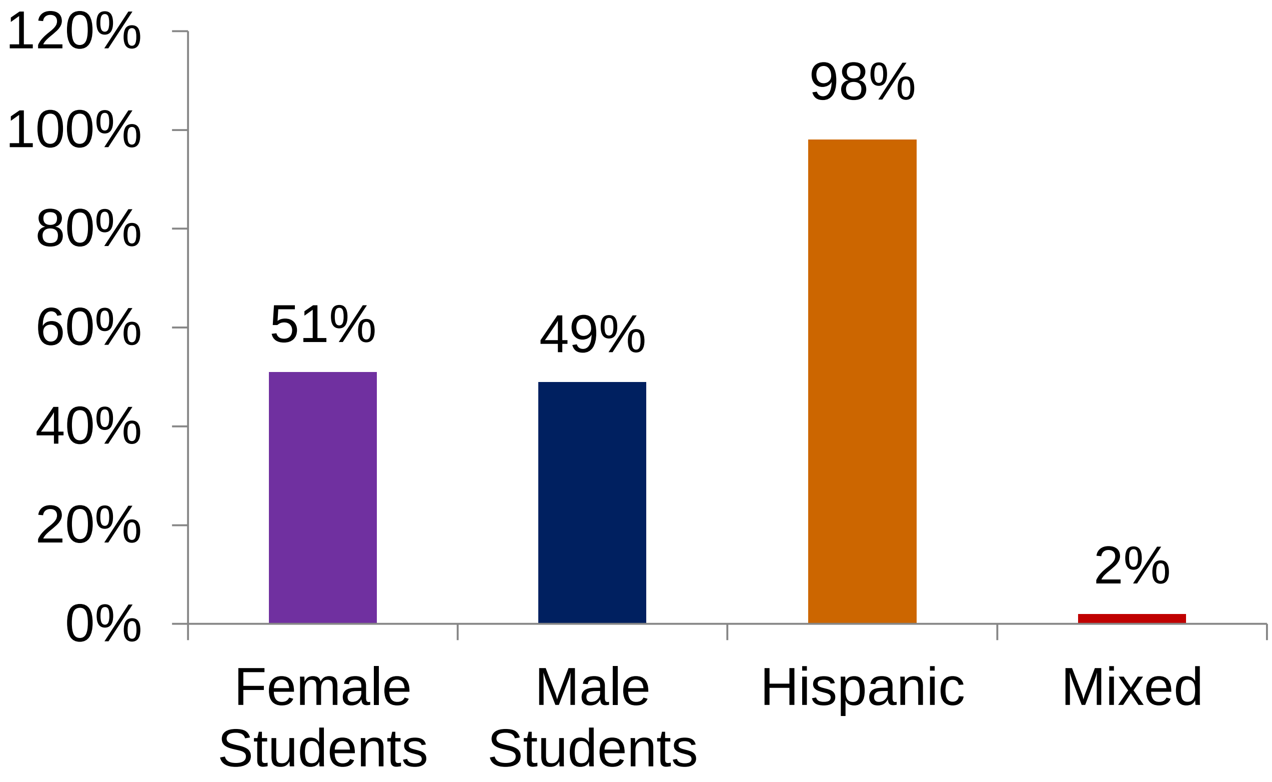
We expected Building Blocks software to benefit all children, but to be particularly beneficial for those with relatively high vocabulary.

Schools

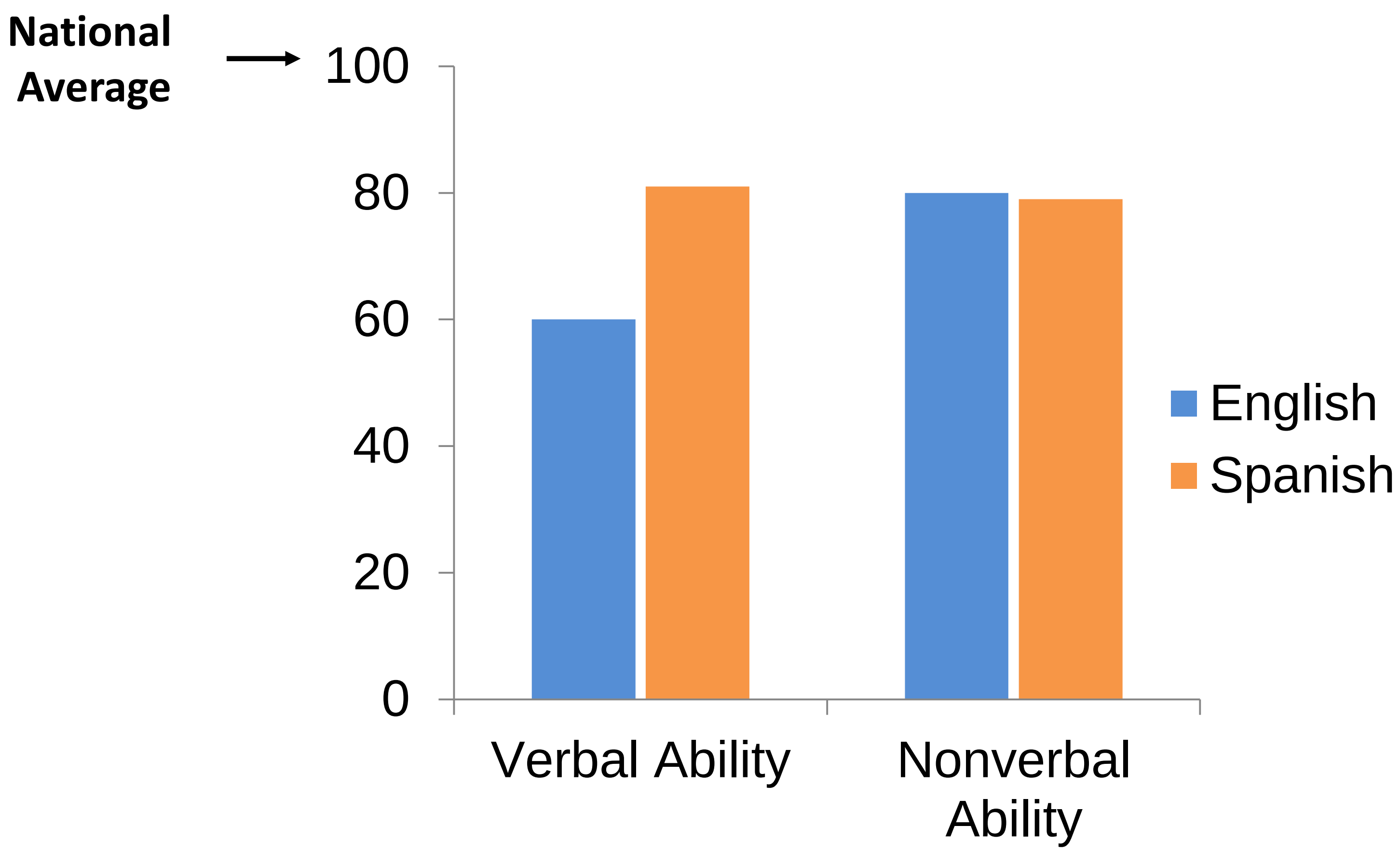
5 Title 1 schools in Houston TX

- 41 kindergarten classrooms with full-day programming
- Hispanic students, *M* (*SD*) = 86% (13%)
- ELLs *M* (*SD*) = 50% (6%)
- Free or reduced lunch eligibility, *M* (*SD*) = 96% (3%)

Participants Gender and Ethnicity (*n* = 270)



Norm-referenced Standard Scores at Pretest



Research Design

- Participants randomized from within classroom to CAI in (a) *Building Blocks* or (b) *Earobics Step 1*
- 90 minutes of instruction a week for 21 weeks
  - Two 45-minute (8 schools) or three 30-minutes (1 school) sessions
- *Building Blocks software* – games targeting numeric & quantitative understandings
  - e.g., counting, subitizing, comparing & ordering numbers, arithmetic

- *Earobics software* – games targeting phonological awareness
  - e.g., segmenting, blending, sound matching

Computer Assisted Instruction (CAI)

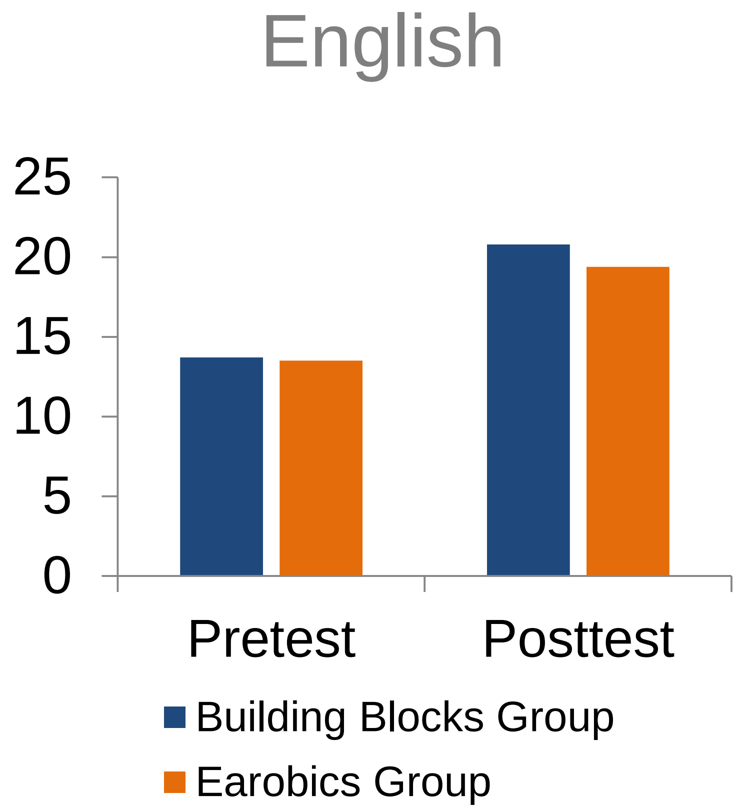
- Took place in schools computer lab during ancillary instructional block designated for computer time
- Children worked individually with the adaptive software programs
  - Instruction adjusted to match the level of ability demonstrated by the child
- Bilingual research assistants provided behavioral supervision & technical assistance

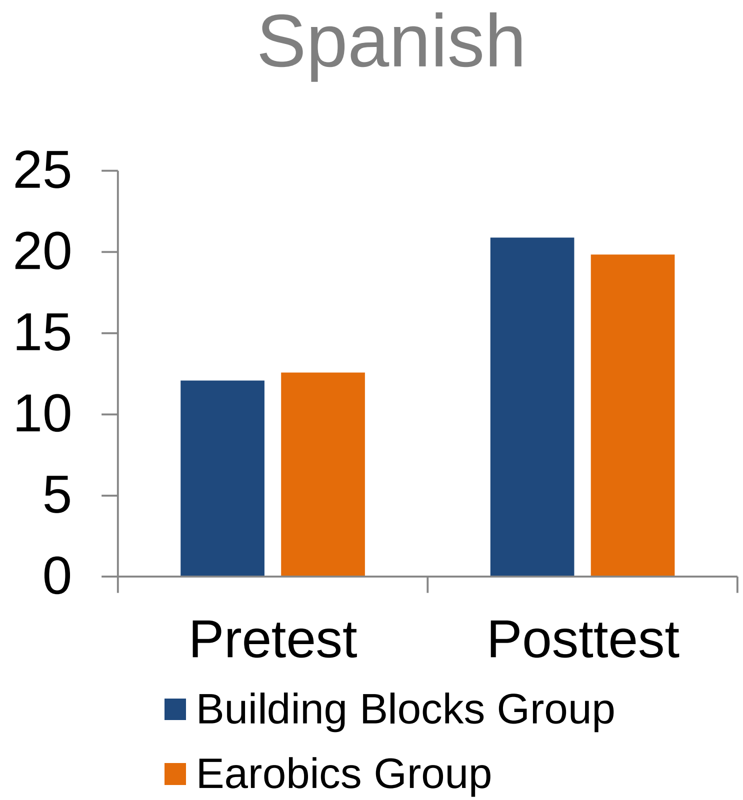
Dual Language Data Collection Plan

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

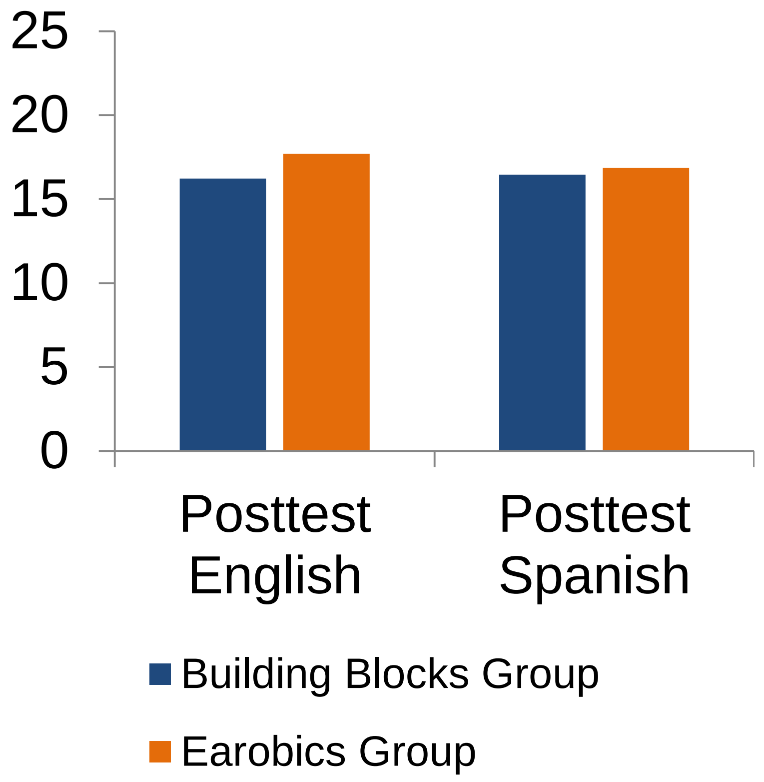
Note. English and Spanish math tests were administered at pretest and posttest, unless the child failed a language screen. REMA is Research Based Early Maths Assessment; EOWPVT is Expressive One Word Picture Vocabulary Test; SPAN is Spanish; SBED is Spanish Bilingual Edition.

Descriptive Statistics: Numeracy





Descriptive Statistics: Applied Problems



Treatment Effects and Impact of Vocabulary

- Treatment effects were examined separately by language of test administration using multiple regression analyses

- Predictors of post-intervention numeracy
  - Pre-intervention numeracy and group
  - Vocabulary
  - ~~Vocabulary × group~~

- Predictors of post-intervention applied problems
  - Pre-intervention numeracy and group
  - Vocabulary
  - ~~Vocabulary × group~~

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.

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 – Treatment Effects

- Spanish version of *Building Blocks* software led to reliable improvements
- Effect sizes (Spanish: numeracy = .26; applied problems = .31)
  - Exceed WWC threshold of .25
  - Commensurate with other CAI research and meta-analyses (e.g., Cheung & Slavin, 2013; Harskamp, 2014; Moyer-Packenham & Westenskow, 2013)
  - Consistent with English version (i.e., .43 & .37; Foster et al., 2016)
  - Comparable to other numeracy interventions (Dyson et al., 2015)
  - Represent learning over above that due to classroom instruction & maturation

Discussion – Impact of Vocabulary on Mathematics

- English vocabulary predicted
  - English applied problems
- Spanish vocabulary predicted
  - English numeracy
  - Spanish numeracy
  - Spanish applied problems
- Vocabulary (i.e., 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)

Implications

1. Assess math skills in English and Spanish for Hispanic ELs
   – May help teachers identify math concepts that students are (a) proficient, (b) in need of further instruction, or (c) need to generalized from Spanish to English

2. Pay more attention to relationship between child's language status/proficiency and his/her early math competencies
   – Compliment math intervention with language intervention

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

Conclusion

- Provides support for use of Building Blocks as a supplemental math program for Hispanic ELL kindergartners from low-income backgrounds
  - Adaptive computer software programs such as Building Blocks software may be help decrease risk for school failure

- Impact of vocabulary on academic outcomes is not limited to reading
  - Vocabulary should be considered with planning math instruction

DISCUSSION QUESTIONS

Question #1

a. What are the challenges of fostering the early learning of mathematics in ELs?
b. How can computer assisted instruction be used within classrooms and schools to support mathematics learning of Hispanic ELs?
c. Describe what you think of when you consider well-implemented CAI in mathematics?

Question #1 Response

a. Teaching academic language or specialized math terminology; balancing explicit instruction (e.g., math terminology and problem solving procedures) with student directed learning; incorporating discussion into classroom-based math instruction
b. Spanish CAI in math can be used to foster the learning of math concepts and skills in the child's native language. English CAI in math can be used to facilitate transfer of math skills from Spanish to English.
c. CAI that targets fundamental learning goals, adjusts & differentiates instruction, & teaches to mastery; but is also tied to classroom instruction

Question #2

- How do you make an English mathematics curriculum accessible and comprehensible to young Hispanic English Learners?

Question #2 Response

- Explicit instruction of mathematics terminology (e.g., factor)
  - Definition #1: a multiplicative relationship between a set of numbers (e.g., 3 and 8 are factors of 24).
  - Definition #2: an issue or event that helps explain why something happened (e.g., bombing of pearl harbor led to a formal declaration of war against Japan)
- Explicit instruction of cognates (http://myedplus.org/pluginfile.php/9762/mod_resource/content/0/ListOfMathCognates.pdf)
  - Segment – Segmento
  - Zero – Cero
  - Equal - Igual

Question #2 Response

- Provide opportunities for English Learners to discuss content/Peer assisted learning
  - e.g., use content-specific vocabulary words when explaining how they solved a math problem
- Integrate language and mathematics instruction
- Provide visual (e.g., base ten blocks) and verbal supports
  - Gives a concrete way to work with abstract math concepts
- Engage students with challenging mathematics tasks

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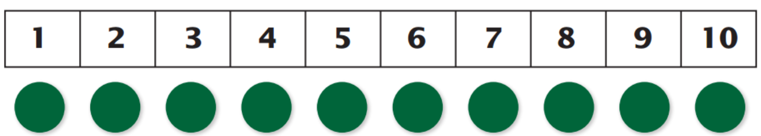
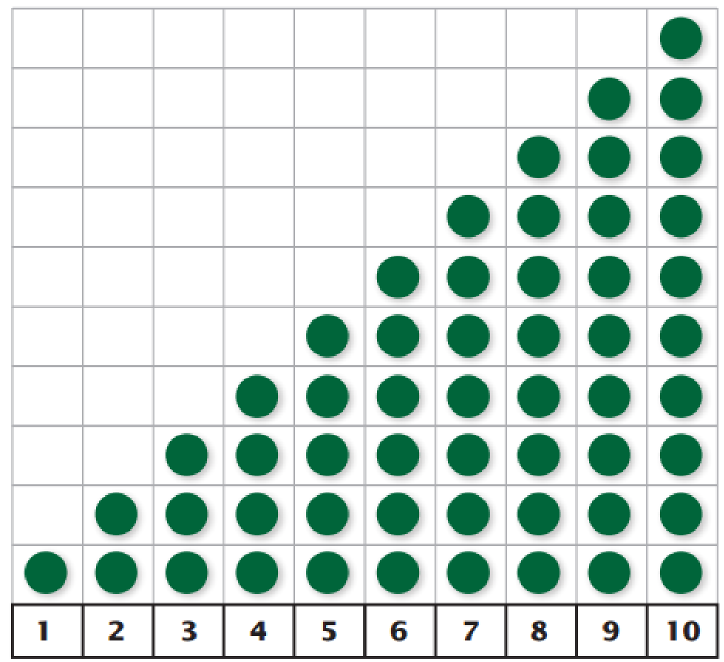
Visual Cues

Sample Number List



Sample Cardinality Chart



Question #3

- In the present study, mathematical learning did not transfer from one language to another language. In your opinion, what is required to foster transfer of mathematics learning from Spanish to English? Is the transfer of mathematical learning from English to Spanish any different?

Question #3 Response

Research design issues that may affect sensitivity to detect transfer

- Evidence of positive transfer may be revealed in the form of
  - *Differences in the level of ultimate attainment*—requires a design that follows students longitudinally and assesses the extent to which students consolidate what has been learned in both languages in such a way that produces superior ultimate performance by students who have been instructed bilingually
  - *Differences in the rate of acquisition*—requires a design that can track the time course of acquisition of a skill using repeated measures at short intervals (i.e., single subject experiments) to detect whether bilingually instructed students reach earlier mastery.

Question #3 Response

Curricular issues that may affect affect sensitivity to detect transfer

- We lack curricula that ”teach for transfer”.
- Students are often instructed sequentially. Content is instructed initially in the L1 and later transitioned to instruction through the L2. There is an implicit assumption that students will figure out for themselves how content knowledge gained in the L1 is applicable to what they are learning in the L2. This could lead to large individual differences in transfer.
- Instruction that makes explicit to students the mappings between knowledge gained in L1 and L2 may strengthen positive transfer effects.

Question #4

- Are there aspects of language other than vocabulary that may influence the learning of mathematics?

Question #4 Response

Beyond Vocabulary…..

- Functional Language Analysis provides a framework for understanding the demands of academic language beyond the identification of unfamiliar vocabulary (Fang & Schleppegrell, 2008).
- Huang & Normandia (2008) identify several linguistic features that that need to be deconstructed in order to identify the relevant mathematical concepts at play in word problems. Some among these with examples by the authors are:
  - Mood—use of interrogative mood vs imperative mood— “how many...?” vs “solve” or “prove”.
  - References—demonstratives and pronouns– that allow establishment of cohesive links between new and already established information.
  - Nominalization—use of a verb or modifier as a noun– “museum admitted” nominalized as “cost of admission equals…”

THANK YOU!

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