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PEABODY research institute

Middle School Math Follow-Up: What Math Competencies Look Like Six Years after a Pre-K Math Intervention

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With thanks to (Current study) Kerry Hofer, CoPI
(Original study)
Mark Lipsey, CoPI
Doug Clements and Julie Sarama,
University of Denver

Original Building Blocks Scale-Up Study

- The *Building Blocks for Math Pre-K Curriculum* (Clements & Sarama, 2007) was designed to help young children learn math

- Nashville was 1 location of a multi-site scale-up study funded by the Institute of Education Sciences, **R305K050157**
  - 2006-2007 Training year for teachers
  - 2007-2008 Children attended Pre-K, Full Implementation

Original Building Blocks Scale-Up Sample

- 20 schools randomly assigned to conditions
  - 16 Metropolitan Public schools
  - 4 Head Start centers
- 57 classrooms
  - 31 treatment classrooms (16 public, 15 Head Start)
  - 26 control classrooms (17 public, 9 Head Start)
- Approximately 680 children with PK pre- and post-data
  - Sample was predominantly Black and from low-income households
- Children followed through end of 1st grade

Early Measures

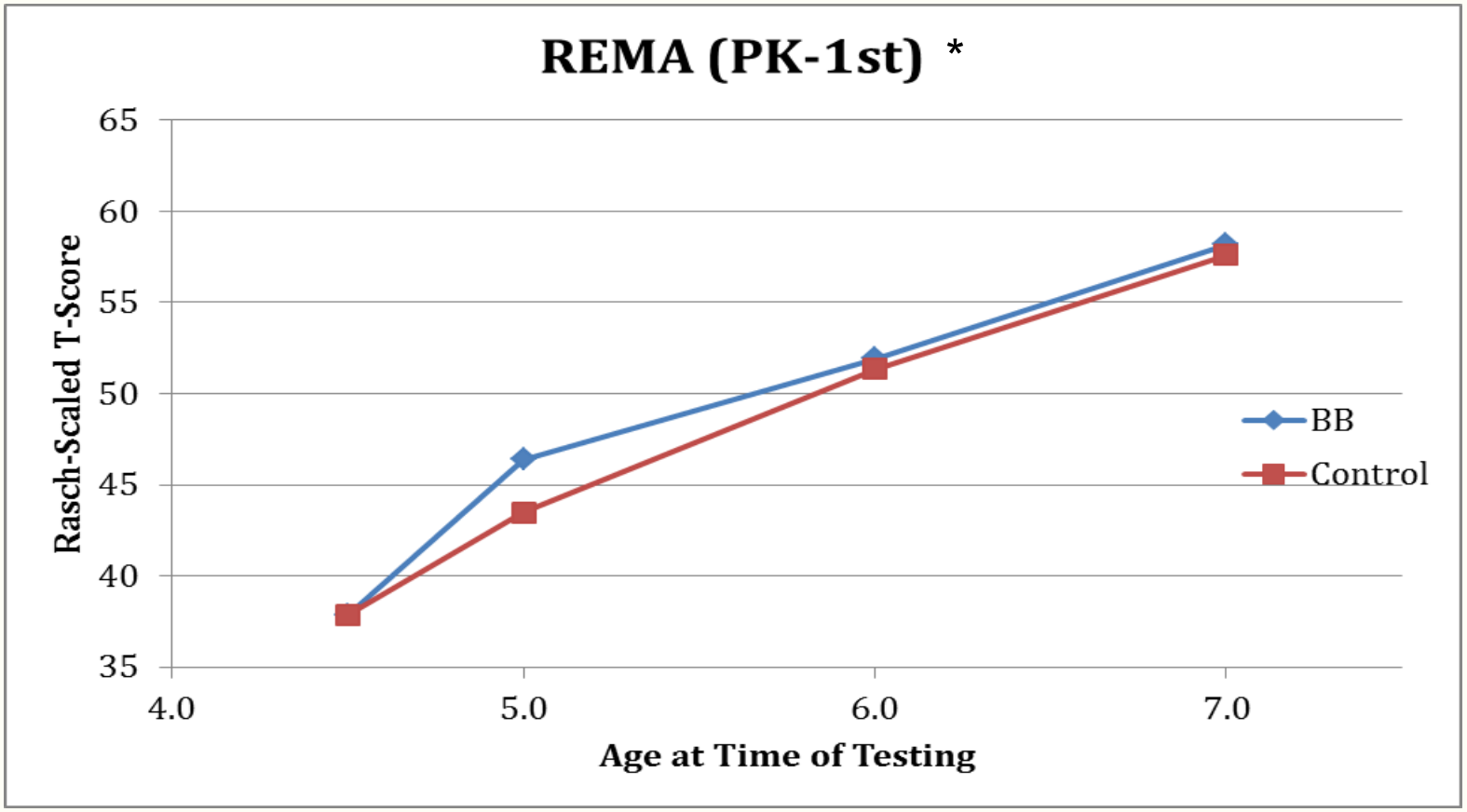
- WJII Subtests
  - Applied Problems
  - Quantitative Concepts
  - Letter Word Identification
  - Story Recall (K and 1st only)
- Other language measure
  - Renfrew Bus Story (Narrative Recall)
- Teacher Ratings
  - Instrumental Competence Scale
  - Cooper Farran Work Related Skills subtest
- Classroom observations in pre-k only (all classrooms)
  - General (Narrative Record, COP, TOP)
  - Fidelity (COEMET)

The Research Early Math Assessment (REMA)

- Developed by Clements and Sarama (Clements, Sarama, & Liu, 2008)
- Originally developed for prekindergarten but items were added to extend to kindergarten and 1st grade
  - The *Numerical Skills* subtest involves developmental progressions in number including verbal counting, object counting, subitizing, number comparison, number sequencing, connection of numerals to quantities, number composition and decomposition, adding and subtracting, and place value.
  - The *Geometry and Algebra Skills* subtest progressions include shape recognition, shape composition and decomposition, congruence, construction of shapes, spatial imagery, geometric measurement and patterning..

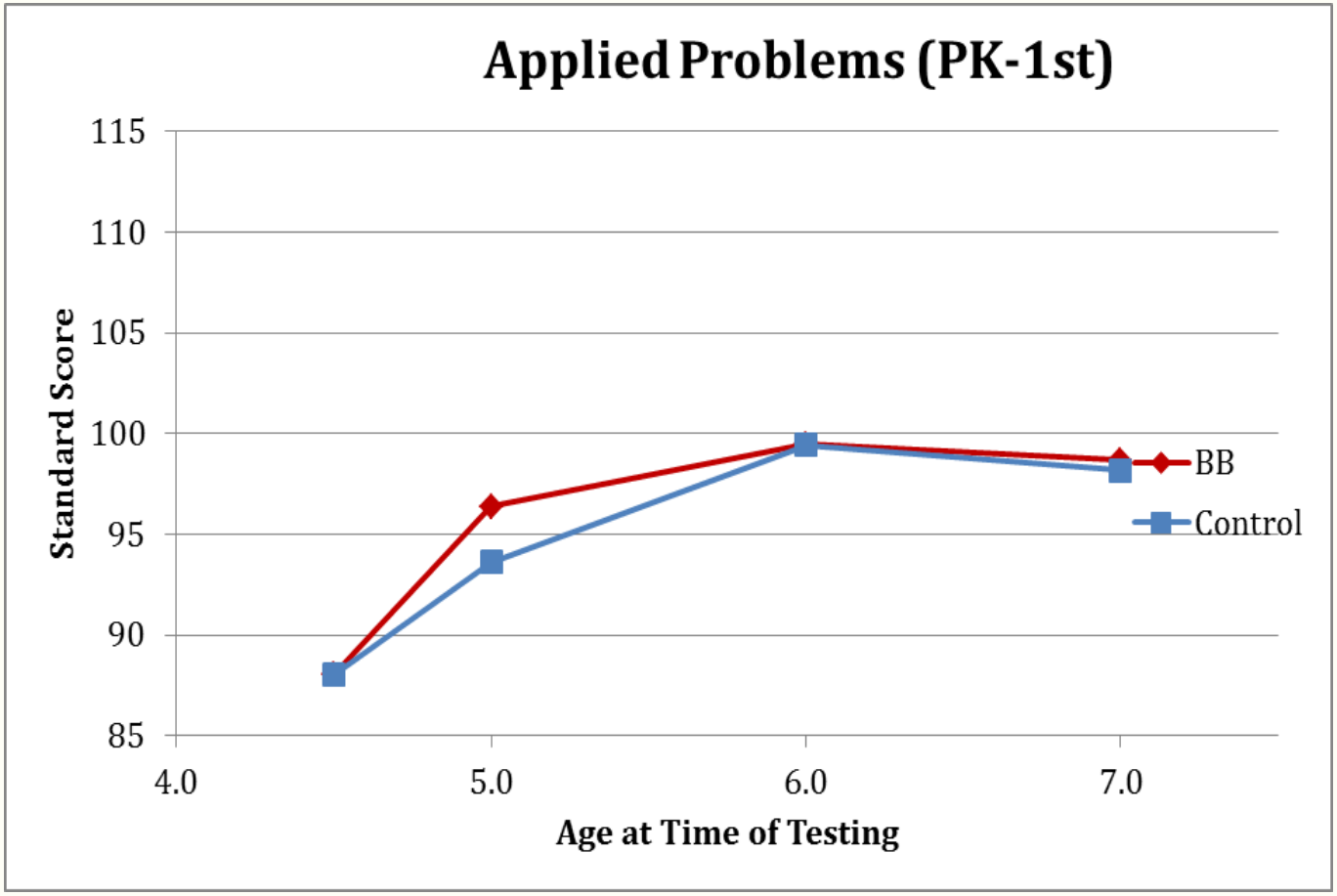
SUMMARY OF EFFECTS ON DIRECT ASSESSMENTS, NASHVILLE ONLY

REMA – Rasch-scaled T-scores



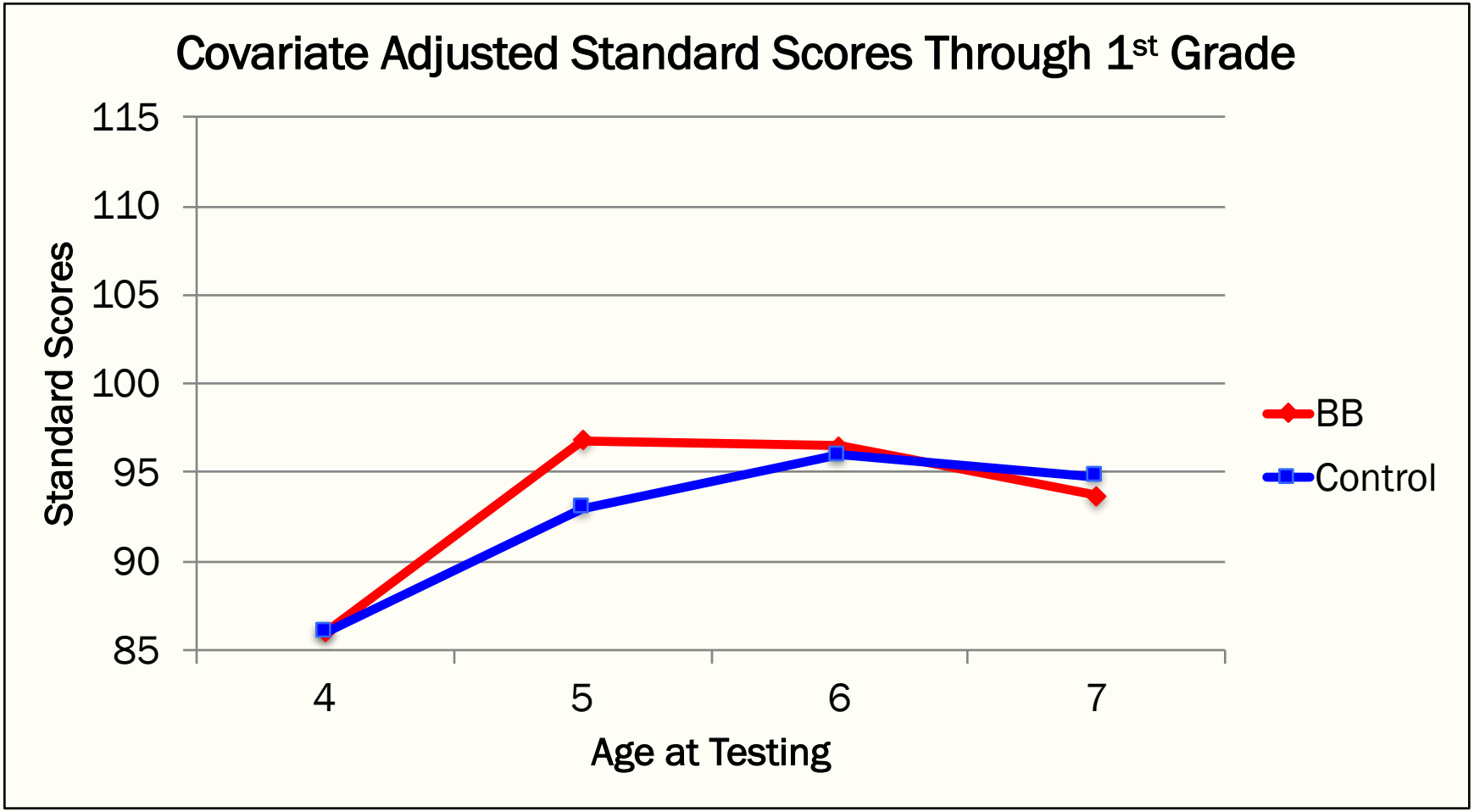
*Covariate Adjusted Scores

WJ Applied Problems*



*Covariate Adjusted Scores

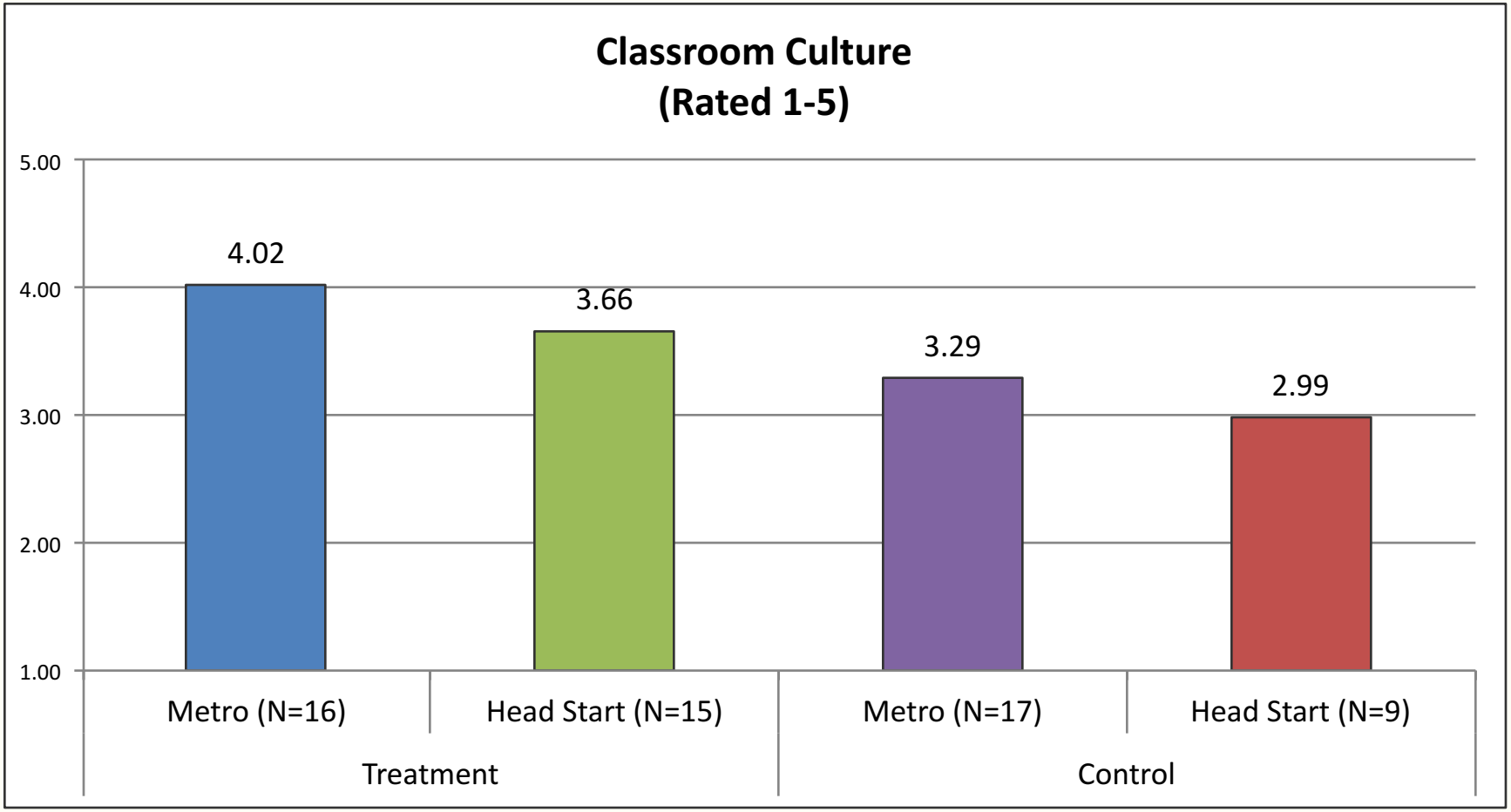
WJIII Quantitative Concepts



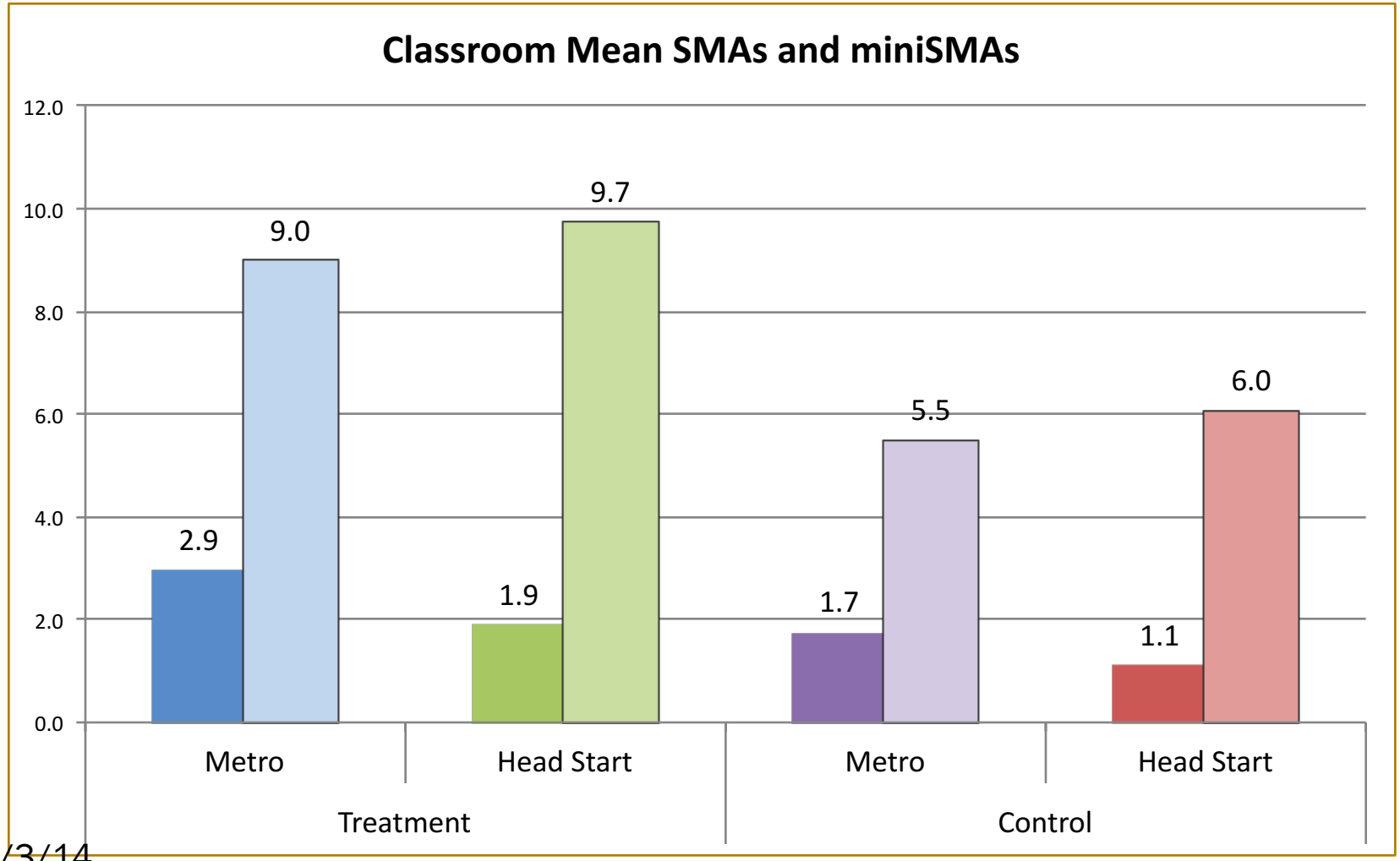
Fidelity

- Measured in Treatment and Control Classrooms
  - COEMET (*Classroom Observation of Early Mathematics—Environment and Teaching;* Sarama & Clements, 2007)
    - Classroom Culture
    - Specific Math Activities (SMA's)
      - Number
      - Quality
    - Miniature Specific Math Activities (miniSMA's)

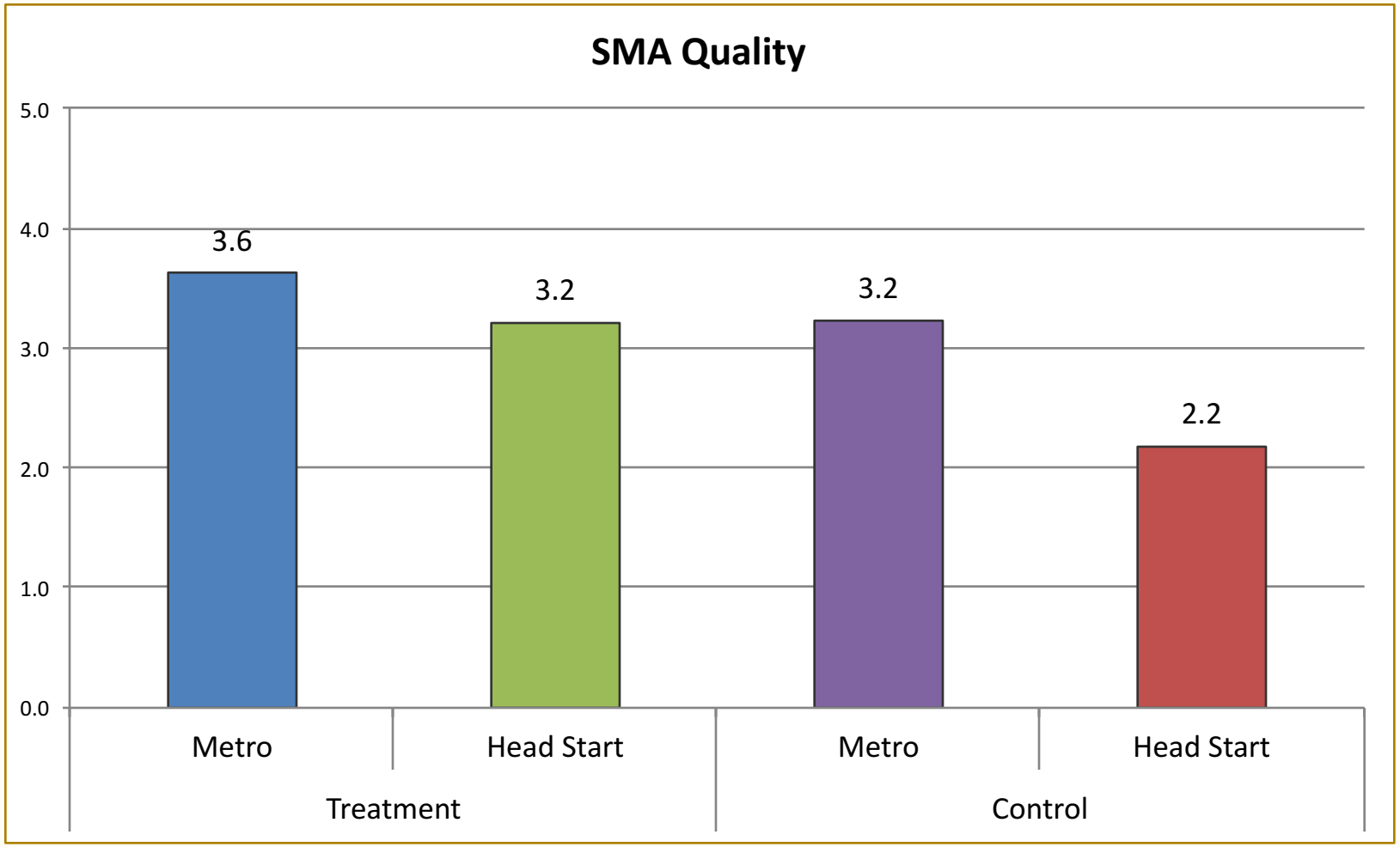
Classroom Culture (COEMET)

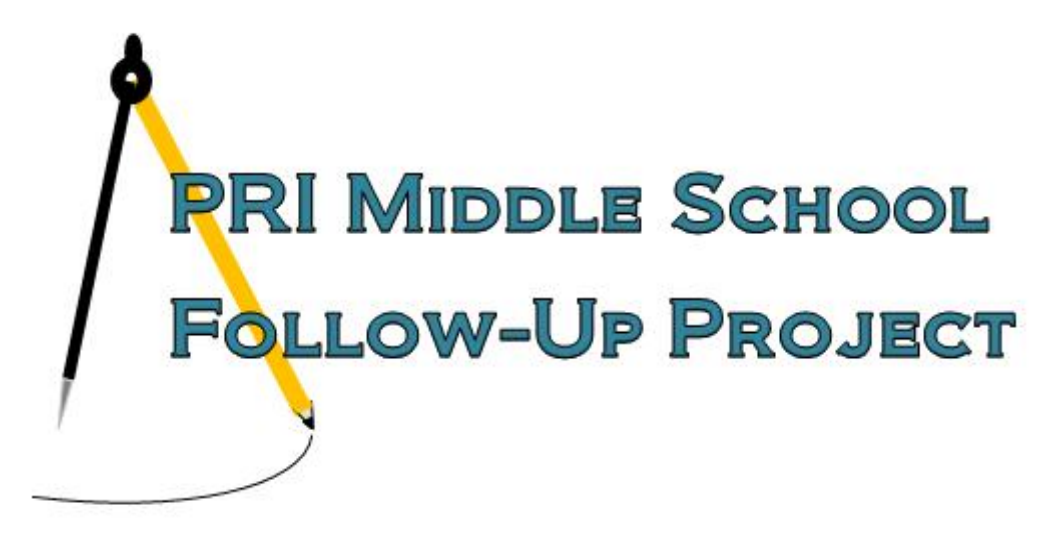


SMA Numbers (COEMET)



SMA Quality (COEMET)





Funded by the Heising Simons Foundation (2013),
Institute of Education Sciences (R305A140126, 2014)

Dale Farran and Kerry Hofer, Co-PI's
Bethany Rittle-Johnson, Gavin Price and Bruce McCandliss, Investigators

Follow Up Sample

- 771 consented students originally
  - 16 withdrew in 1st grade
  - 29 no longer in Tennessee
  - 45 students not located in state data base
  - 53 in Tennessee but not in Nashville
  - **34 students' Nashville parents declined**
  - 72 students located but never responded (backpacks!)

90 Students unrecoverable

- 523 students re-consented – all from Metro Nashville Public Schools (MNPS) (77% retained; 5% declined)
  - 521 assessed this past spring
    - 317 BB treatment children (70% of original group)
    - 205 Control children (64% of original group)

76 Schools

- 31 elementary schools
  - 15% children retained in grade
  - 2.4 students assessed per school
- 27 Middle schools
  - 10.3 students assessed per school
- 18 Izone or Charter schools
  - Izone – independent schools grouped because they were failing
  - Charter – Nashville new and resistant to charters. Must serve low income students in areas where schools are failing
  - 9.7 students assessed per school

Demographics

	N	Min	Max	Mean	SD
Age at Time of Testing (in years)	521	10.4	12.5	11.05	0.325
PK Treatment Condition	316	10.4	12.5	11.0	.320
PK Control Condition	205	10.4	12.3	11.1	.327

	Overall		PK Treatment		PK Control	
	Freq	Pct	Freq	Pct	Freq	Pct
Ethnicity						
Black	411	79%	259	82%	152	74%
White	46	9%	23	7%	23	11%
Hispanic	42	8%	20	6%	22	11%
Other	22	4%	15	5%	7	4%
Gender						
Male	228	44%	140	44%	88	43%
Female	293	56%	176	56%	117	57%
Pre-K School System*						
MAC	210	40%	152	48%	58	28%
MNPS	311	60%	164	52%	147	72%

Demographics (con't.)

	Overall		PK Treatment		PK Control	
	Freq	Pct	Freq	Pct	Freq	Pct
FRPL Eligibility (from last year)						
Reduced Price Lunch	21	4%	18	6%	3	1%
Free Lunch	454	87%	278	88%	176	86%
Non-subsidized Lunch	39	8%	19	6%	20	10%
Missing	7	1%	1	<1%	6	3%
Special Education Designation (from last year)						
Speech/Language	10	2%	7	2%	3	1%
Physical Impairment	16	3%	5	2%	11	5%
Delay/Learning Disability	50	10%	26	8%	24	12%
Other	5	1%	3	1%	2	1%
None	440	84%	275	87%	165	80%

KeyMath 3 Diagnostic

1. ***Numeration*** - The Numeration subtest measures an individual's understanding of whole and rational numbers.
2. ***Algebra*** - The Algebra subtest measures an individual's understanding of pre-algebraic and algebraic concepts.
3. ***Geometry*** - The Geometry subtest measures an individual's ability to analyze, describe, compare, and classify two- and three-dimensional shapes. It also covers topics such as spatial relationships and reasoning, coordinates, symmetry, and geometric modeling.

Woodcock Johnson Achievement Battery III: Quantitative Concepts Subtest (carryover from original)

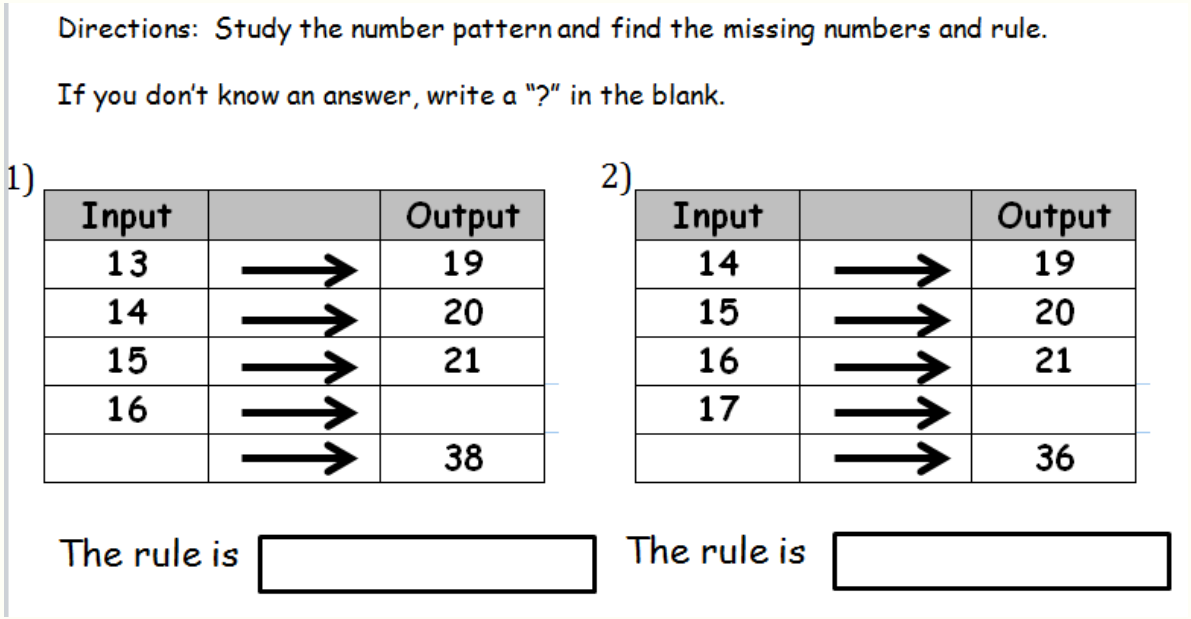
- Assesses students' knowledge of mathematical concepts, symbols, and vocabulary, including numbers, shapes, and sequences; it measures aspects of quantitative math knowledge and recognition of patterns in a series of numbers.
- Examples (Part A):
  - *What does a decimal point look like?*
  - *What does this abbreviation mean?* **Oz**
- Example (Part B):
  - *For each problem, tell me the number that goes in the blank space.*

    ____ *5 6 7*

Pre-Algebra Task (Functional Thinking)

Developed by Bethany Rittle-Johnson this task consists of 6 'tables' in which the student has to fill in the missing Input number, Output number, and Rule. The maximum possible score is 18 (3 points per table).

Examples:



Directions: Study the number pattern and find the missing numbers and rule.

If you don't know an answer, write a "?" in the blank.

1)

Input		Output
13	→	19
14	→	20
15	→	21
16	→	
	→	38

The rule is _____

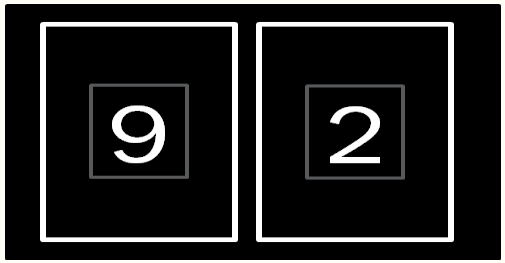
2)

Input		Output
14	→	19
15	→	20
16	→	21
17	→	
	→	36

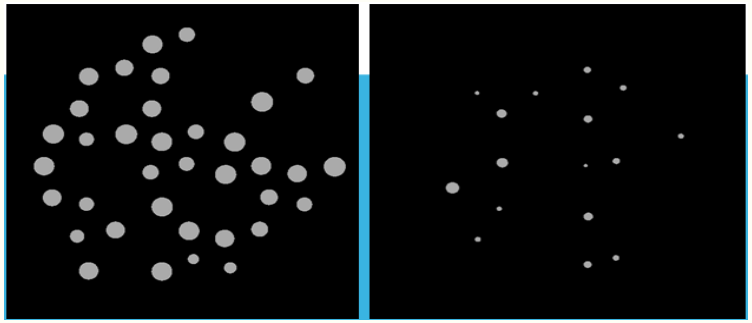
The rule is _____

Math-Specific Neurocognitive Measures

1. ***Symbolic Number Comparison Task.*** This task assesses children's symbolic Approximate Number System (ANS) acuity through the presentation of two single digits simultaneously.



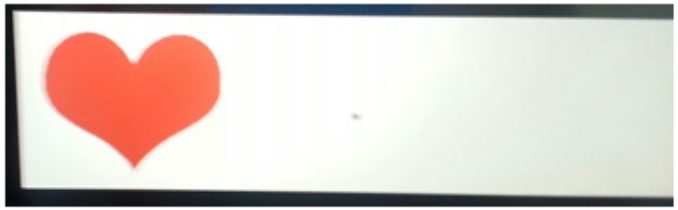
2. ***Non-symbolic Number Comparison (ANS).*** Student must decide which side of the screen contains more dots.



Domain General: Executive Function and Visuospatial Skill

1. ***Working Memory (Backward Corsi Blocks).*** Different numbers of squares light up in a sequence; the student must tap the squares in the reverse. The task consists of 16 total trials made up of 8 2-trial items. The sequence length of squares increases from 2 to 8.
2. ***Attention Shifting.*** Hearts and Flowers (HAF) task tests a student's ability to use attention shifting and inhibitory control by tapping congruent or incongruent sides of the screen based on different stimuli + rule combinations. The task consists of 12 congruent trials, 12 incongruent trials, and 48 mixed trials.

Congruent Trials (student presses the button that corresponds to the SAME side the heart appears on)



Incongruent Trials (student presses the button that corresponds to the OPPOSITE side the flower appears on)

Other Measures

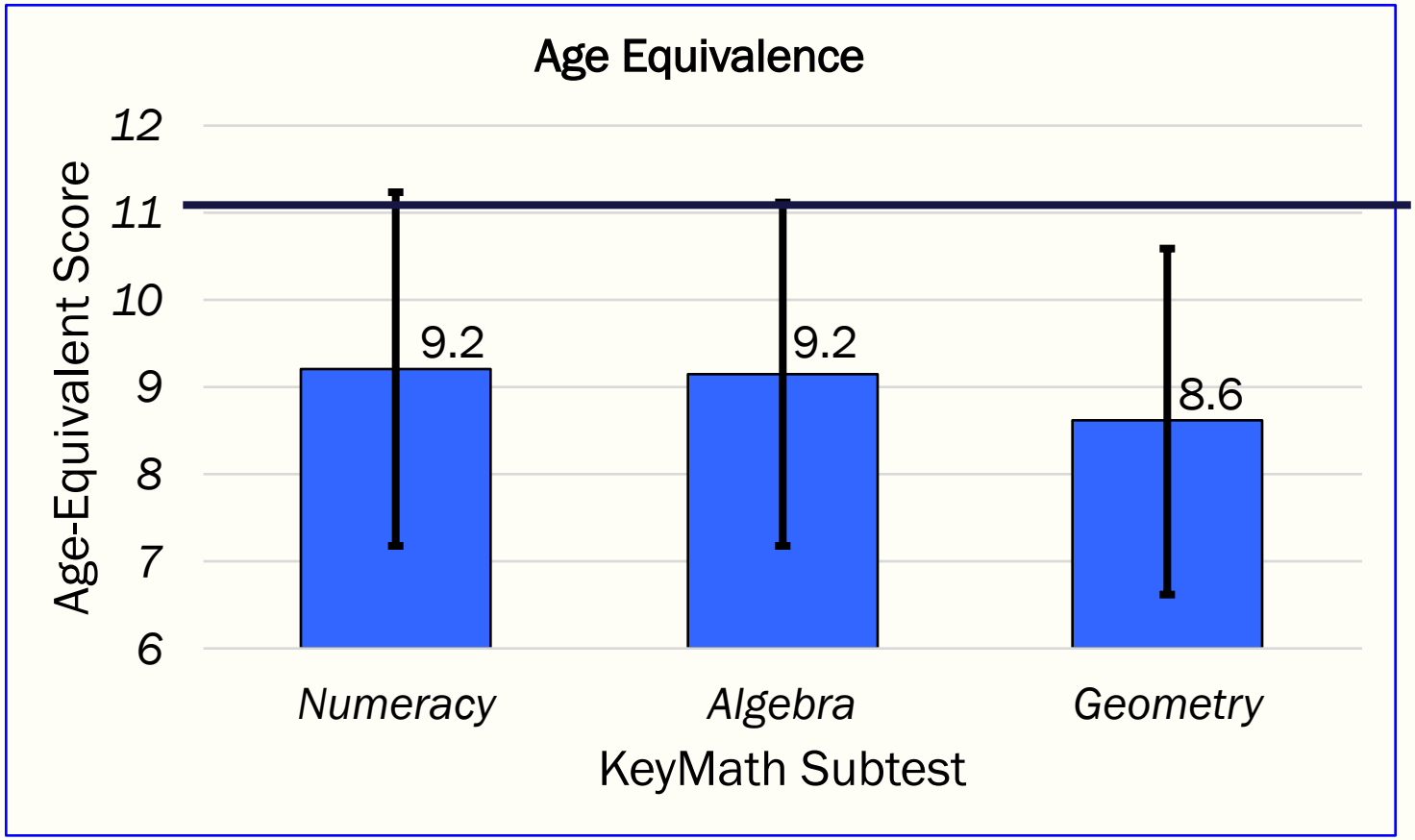
1. End of Grade State Test Scores (TCAP): Math and Reading
2. Course Grades: Reading (Language Arts) and Math
3. Student Survey: *Feelings about Math*
4. Teacher Survey
   - Classroom Characteristics
   - Student Performance
   - Student Motivation and Work Effort

Very preliminary analyses. Data collected this past May. More complex analyses have been conducted as findings emerge. And more will follow.

5TH GRADE OUTCOMES

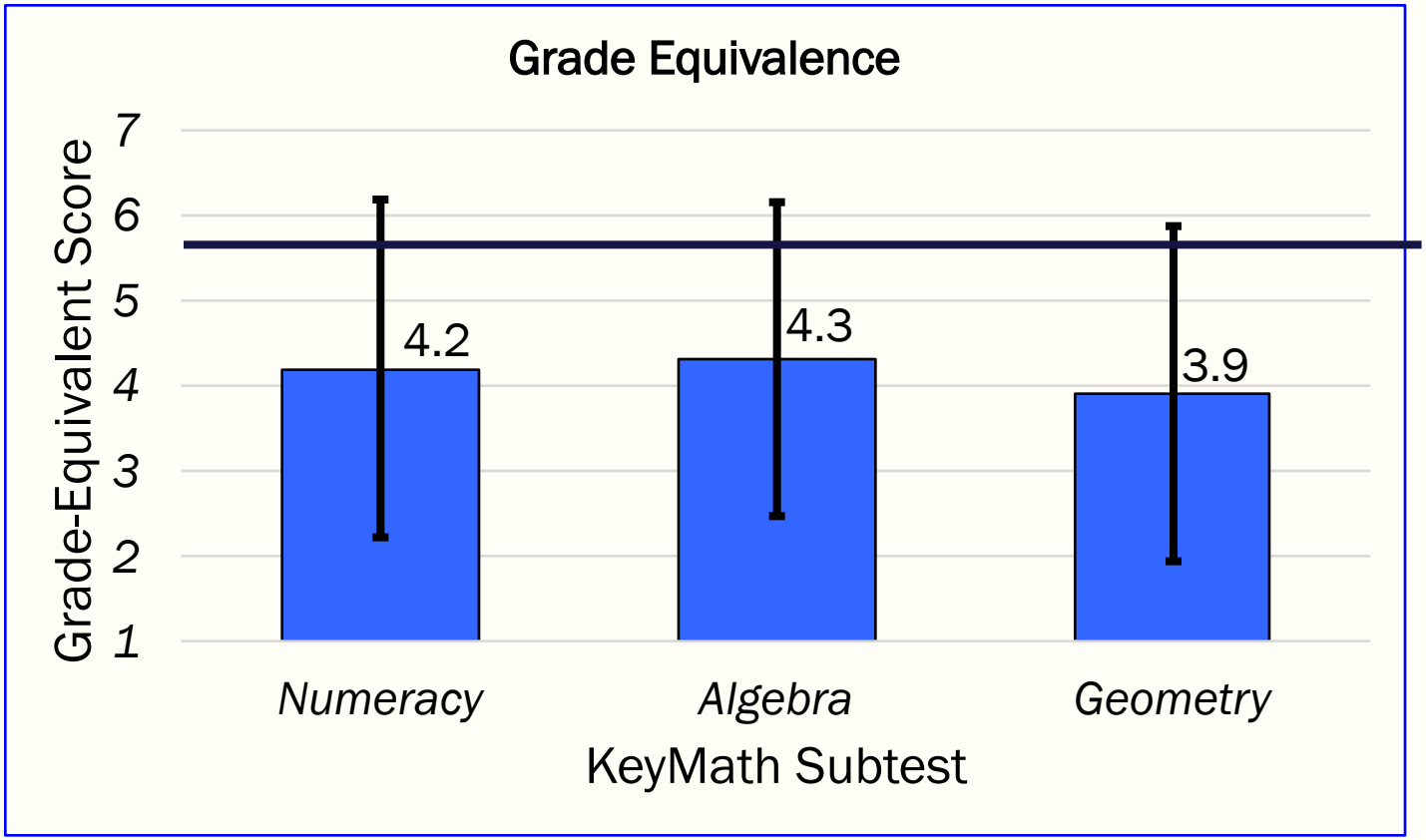
Standardized Math Measures

KeyMath Assessment



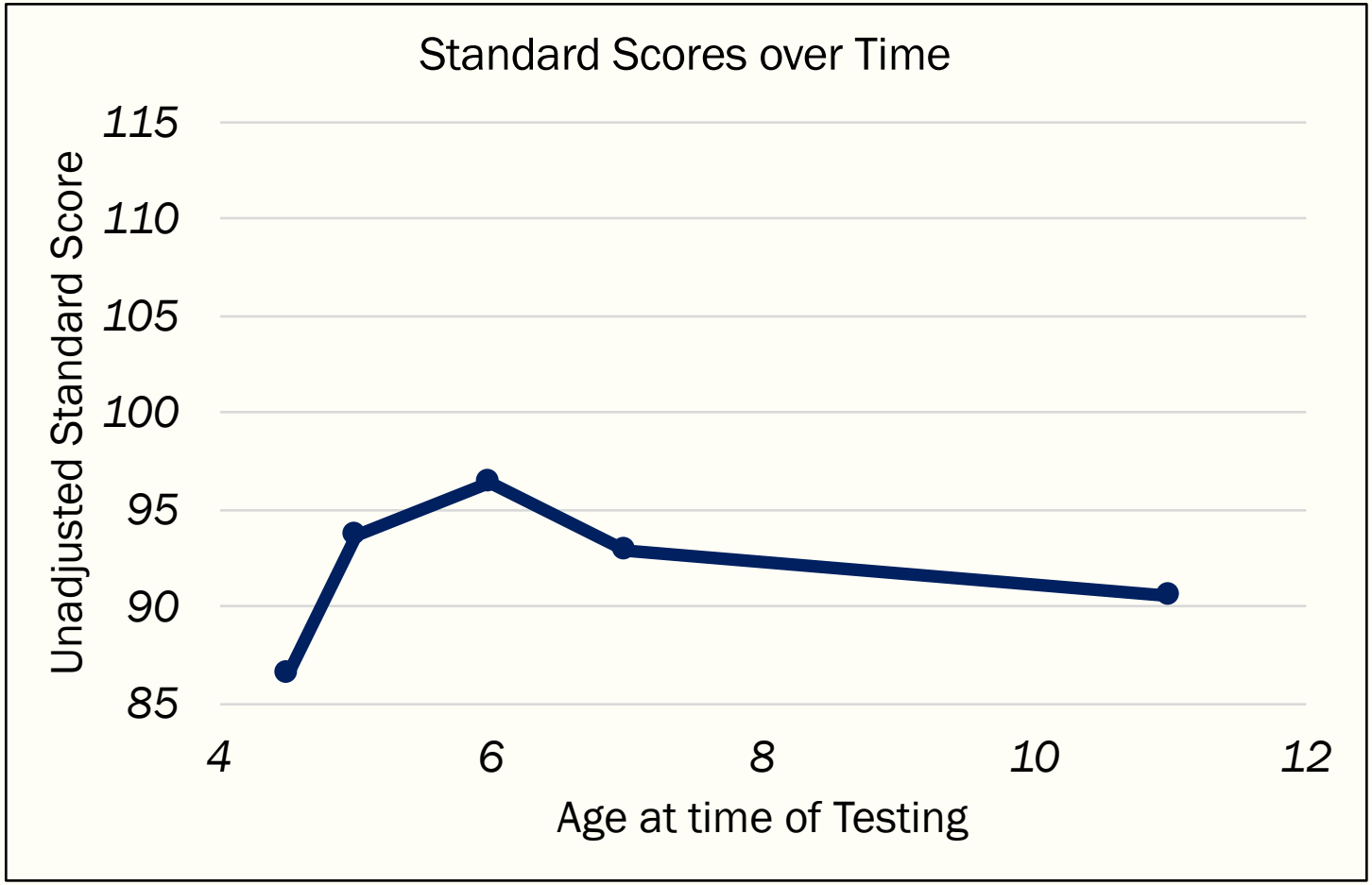
Standardized Math Measures

KeyMath Assessment



Standardized Math Measures

WJIII Quantitative Concepts Assessment



Intercorrelations Among Assessments of Traditional Math

	KM NUMBER	KM ALGEBRA	KM GEOMETRY	QUANT CONCEPTS
KM NUMBER	--			
KM ALGEBRA	.83	–		
KM GEOMETRY	.69	.66	–	
QUANT. CONCEPTS	.68	.68	.54	–
FUNCTIONS	.66	.66	.45	.60

Correlations between Traditional Math and Neurocognitive Assessments (Accuracy only)

	KM NUMBER	KM ALGEBRA	KM GEOMETRY	QUANT CONCEPTS	FUNCTIONS
SYM NUMBER	.33	.36	.27	.34	.31
ANS ACCURACY	.16	.17	.17	.15	.18
HAF INCONG.	.23	.22	.20	.23	.19
HAF MIXED	.29	.27	.25	.32	.28
BACKWARD SPAN	.35	.31	.31	.35	.27

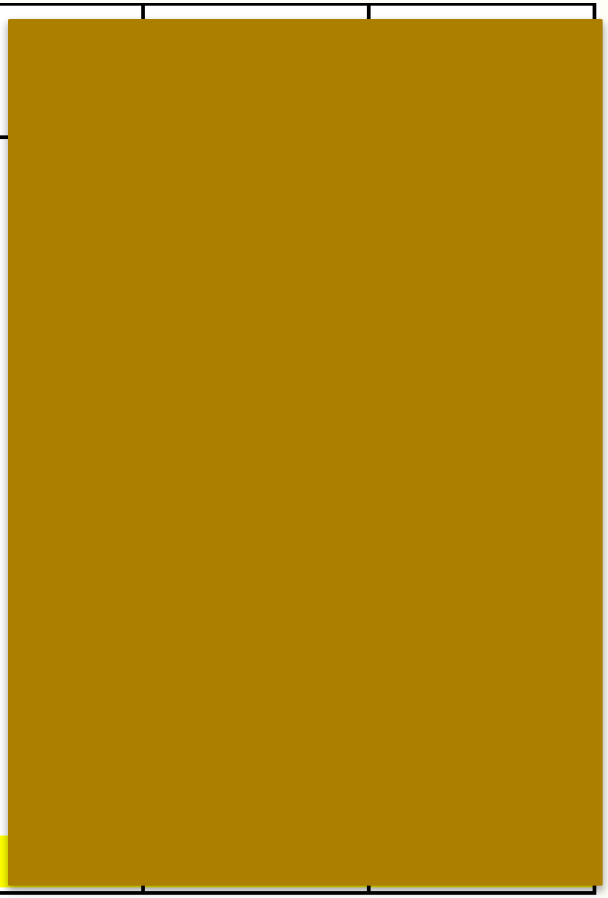
Early Math Matters

- Watts, Duncan, Siegler & Davis-Kean (2014)
  - Existing Dataset: 1364 children sampled nationwide
  - Assessed ages: 4.5, 1st, 3rd, 5th grades and age 15
  - Math Measure: Woodcock-Johnson Applied Problems

- Our Replication attempts (VERY preliminary, but interesting)
  - Existing Dataset: 396 children from very poor families (those in Follow Up sample with valid data for all variables)
  - Assessed ages: 4.5, 5, 6, 7, and 11
  - Math Measure: Woodcock-Johnson Quantitative Concepts
  - Many similar covariates

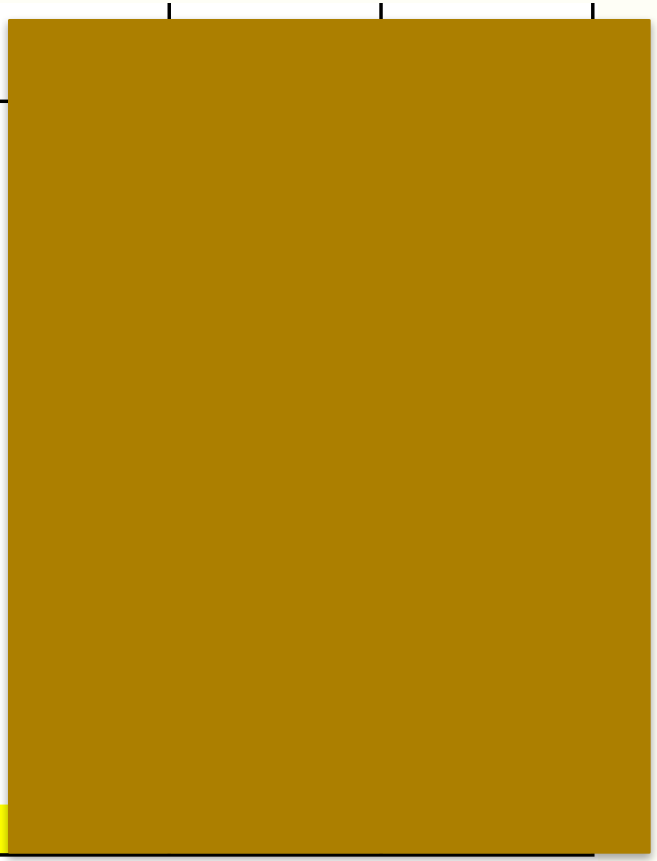
MODEL 1: Predicting 5th grade WJ Quantitative Concepts from 1st grade Quantitative Concepts

Parameter
Intercept
1st grade WJ Letter-Word Scores
Gender
Black
ELL (from PreK)
Grade Level at Time of Outcome Test
Age at Time of Outcome Test
Bus Story Information Score from Beginning PreK
Bus Story MLU from Beginning PreK
Bus Story Complexity Score from Beginning PreK
Bus Story Independence Score from Beginning PreK
ICS Self Regulation Ratings from 1st grade
CF Work-Related Skills Ratings from 1st grade
1st grade WJ Quantitative Concepts Scores



MODEL 2: Predicting 5th grade WJ Quantitative Concepts from 1st grade Quantitative Concepts RESIDUALIZED GAIN

Parameter
Intercept
Beginning PreK WJ Letter-Word Scores
Gender
Black
ELL (from PreK)
Grade Level at Time of Outcome Test
Age at Time of Outcome Test
Bus Story Information Score from Beginning PreK
Bus Story MLU from Beginning PreK
Bus Story Complexity Score from Beginning PreK
Bus Story Independence Score from Beginning PreK
ICS Self Regulation Ratings from Beginning PreK
CF Work-Related Skills Ratings from Beginning PreK
Beginning PreK WJ Quantitative Concepts Scores
Gain in Quantitative Concepts from Beginning PreK to 1st Grade

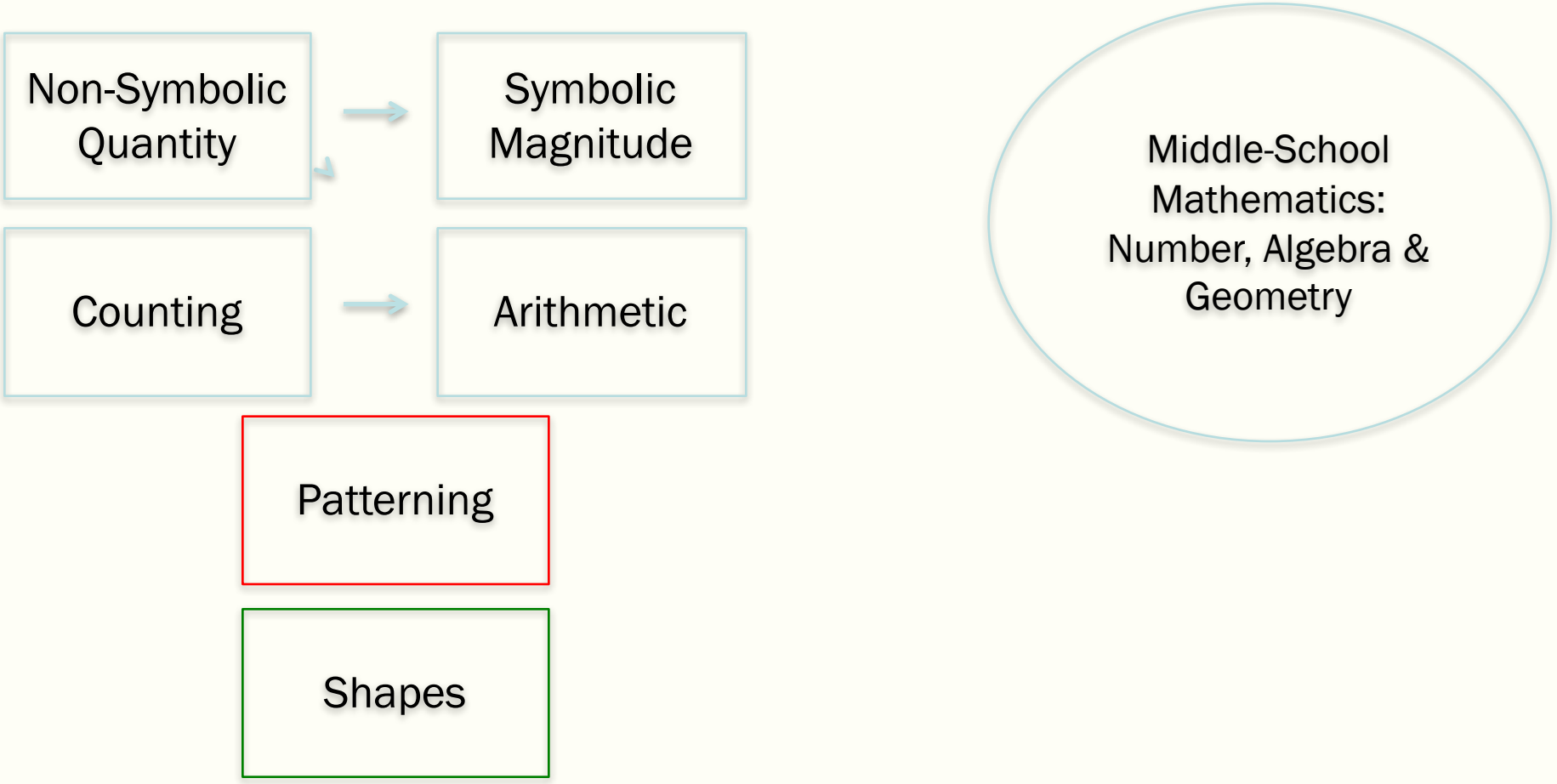


GAIN [including raw gain (1st grade-Beginning Pre-K) and Beginning Pre-K level], using Beginning Pre-K covariates instead of 1st grade

What IS Early Math Knowledge?

- What do 4-6 year olds know about math? What does *math* even mean?
- Bethany Rittle-Johnson regrouped REMA items into early math components
- Traced changes in these competencies from Pre-K through 1st Grade
- Connected those changes to age 11 outcomes

Components created by Bethany Rittle-Johnson



Predictors of School Mathematics Knowledge

Analysis Model

- Regression models for each Age 11 outcome
- Regression models for each Time Point
- Control Variables
  - Background: Gender, ethnicity, age, current grade level, pre-k condition
  - Reading Achievement: WJ Letter-Word
  - Screened for multicollinearity using variance inflation factors (VIF); All VIF values < 5

Summary of Predictors of Age 11 Mathematics Outcomes

	Predictor Grade			
Predictor	Begin Pre-K	End Pre-K	End Kinder.	End Grade 1
Non-Symbolic	All	Num, Alg	Geo	None
Counting	All	None	None	Num, Alg
Symbolic Magnitude	None	Num	Alg	All
Arithmetic	--	--	All	A
Patterning	--	All	All	A
Shape	Geo	Geo	Nor	Nc

Non-Symbolic Quantity → Symbolic Magnitude

Counting → Arithmetic

Patterning

Shapes

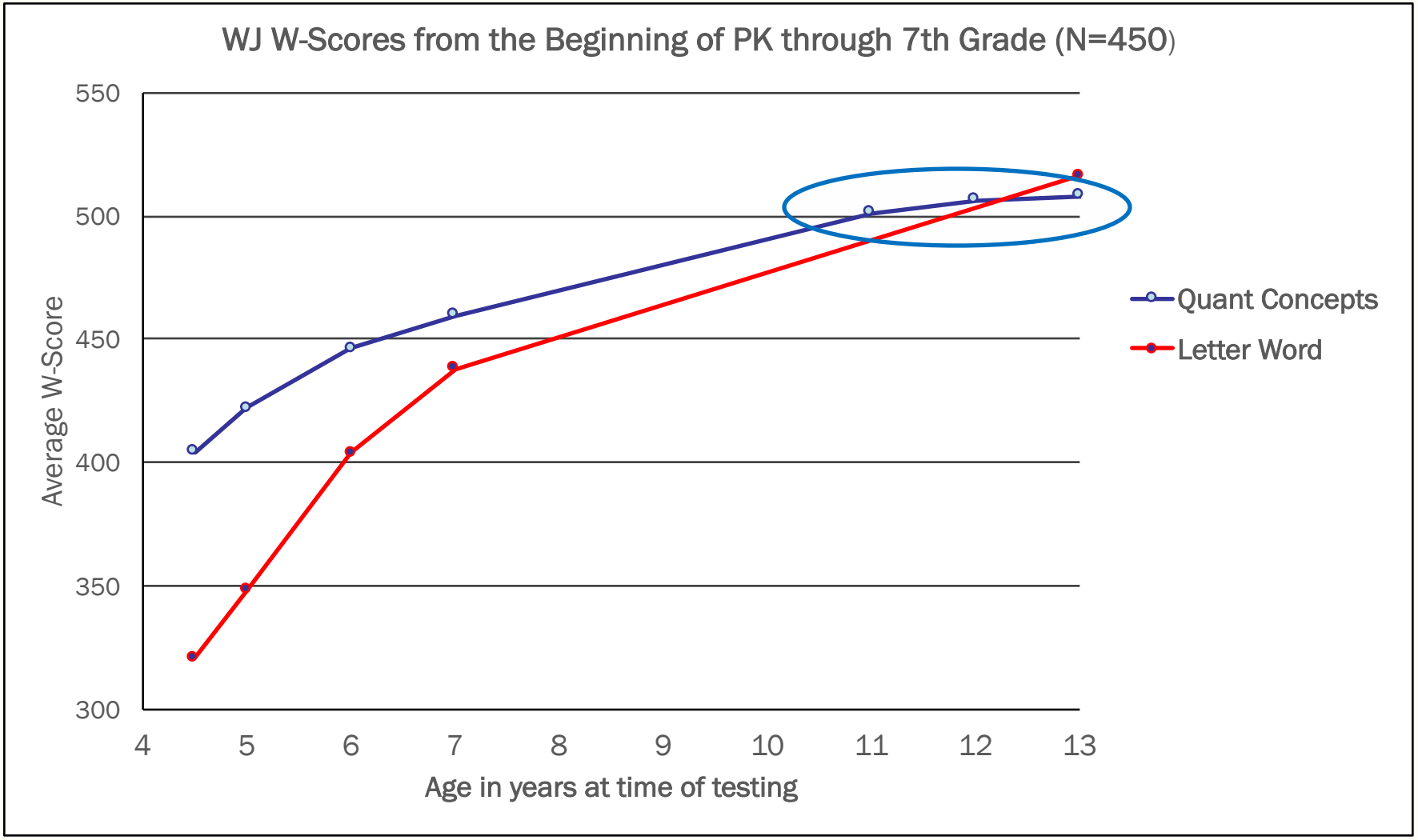
Implications from Early Math Importance

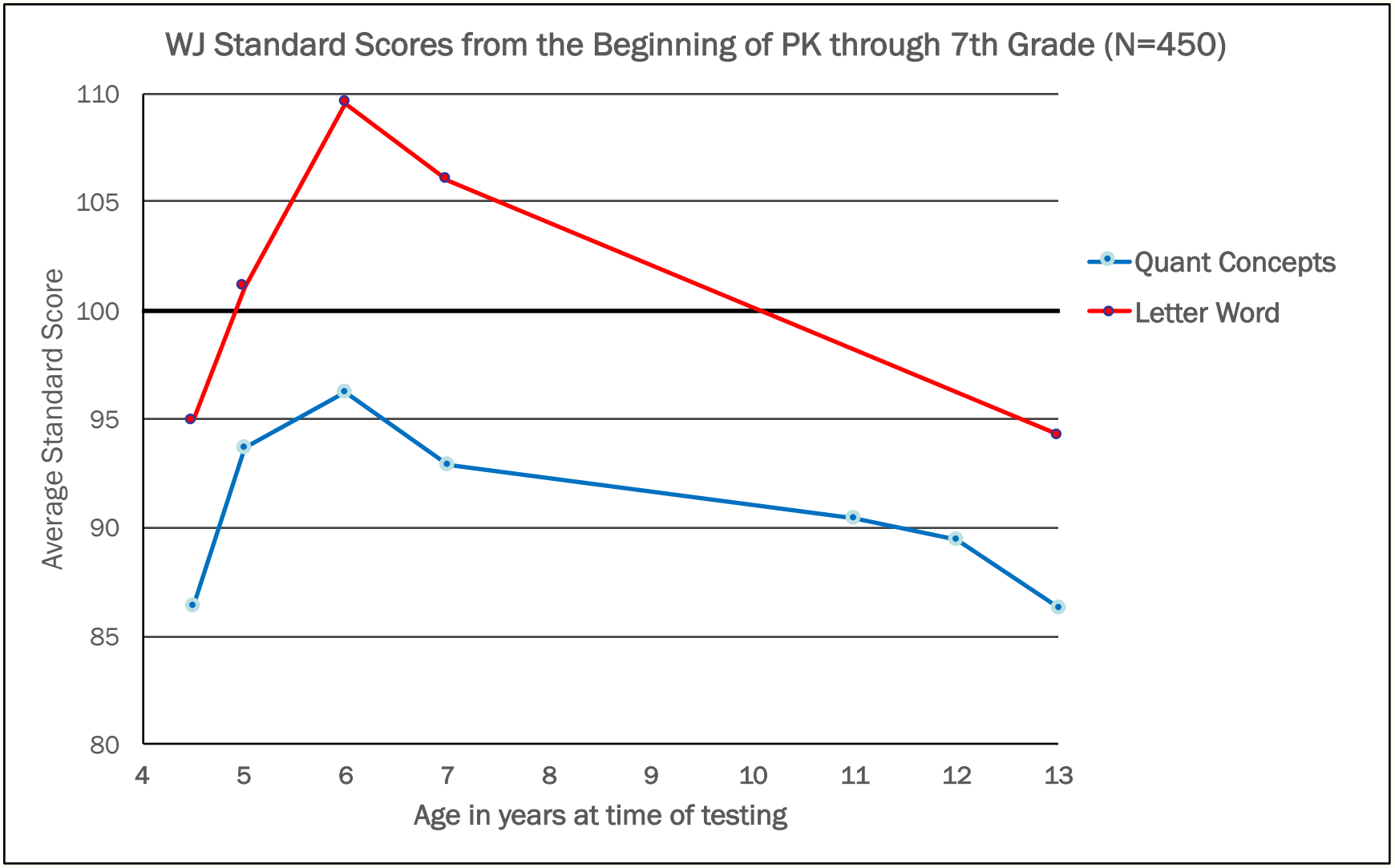
Alternative Explanations

1. Early math skills (including gains) are really a proxy for an unmeasured (unmeasurable?) variable related to curiosity, learning incidentally, a predisposition and interest in mathematical thinking.
2. Early math skills are really a proxy for socioeconomic status (even to variations among a very low income group) and reflect parental interest and time spent on learning and involvement in mathematical thinking.
3. Early math skills and learning more math change the brain in ways we don't understand yet. We do know math levels and math gains are related to gains in early Executive Function skills.

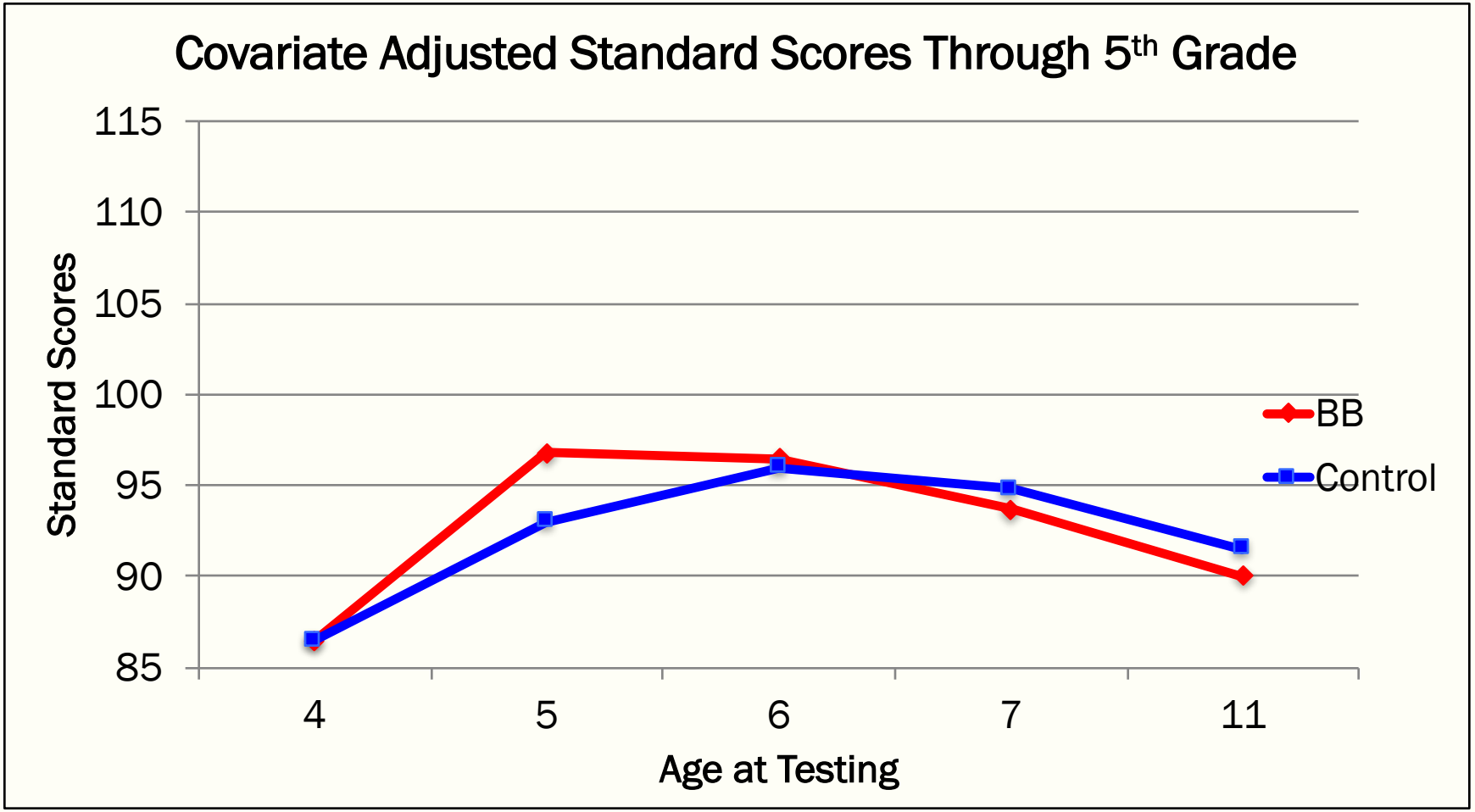
Only one of these suggests that math skills are malleable and that teaching them will result in better school outcomes later.

EFFECTS OF PRE-K MATH INTERVENTION THROUGH 5TH GRADE


WJ W-Scores from the Beginning of PK through 7th Grade (N=450)
Average W-Score
550
500
450
400
350
300
4
5
6
7
8
9
10
11
12
13
Age in years at time of testing
Quant Concepts
Letter Word


WJ Standard Scores from the Beginning of PK through 7th Grade (N=450)
Average Standard Score
110
105
100
95
90
85
80
4
5
6
7
8
9
10
11
12
13
Age in years at time of testing
Quant Concepts
Letter Word

WJIII Quantitative Concepts



Covariate-Adjusted Mean 5th Grade Traditional Math Scores by Pre-K Condition

	Control Group Mean (N=205)	BB Group Mean (N=316)	p-value for Pre-K Condition
Key Math Number Subscale: Age-scaled Score	8.12	7.63	.041*
Key Math Algebra Subscale: Age-scaled Score	8.32	7.79	.029*
Key Math Geometry Subscale: Age-scaled Score	7.67	7.53	.581
WJ Quantitative Concepts: Standard Score	91.47	90.02	.211
Functional Thinking Subtotal: Input	1.79	1.79	.804
Functional Thinking Subtotal: Output	2.83	2.83	.900
Functional Thinking Subtotal: Rule	2.28	2.28	.385
Functional Thinking: Total Score	6.89	6.89	.892
TCAP Math Scale Score 2013-2014	664.68	667.31	.605
TCAP RLA Scale Score 2013-2014	647.97	643.22	.561

Exploring a General Math Factor

Component Matrix[a]

	Component
	1
Key Math Number Subscale: Age-scaled Score	.920
Key Math Algebra Subscale: Age-scaled Score	.911
Key Math Geometry Subscale: Age-scaled Score	.787
WJ Quantitative Concepts Subscale: Standard Score	.826
Functional Thinking: Total Score	.790

Predicting General Math Component by Pre-K Condition

	BB			Control			Mean Difference	Pooled SD	Effect Size
	N	Mean	SD	N	Mean	SD			
GENERALMATH FACTOR	316	-.07	.98	205	.11	1.03	-.18	1.00	**-.17**

But the situation is more nuanced…

	BB			Control			Mean Difference	Pooled SD	Effect Size
	N	Mean	SD	N	Mean	SD			
Black Students	257	-.08	1.10	152	-.01	1.01	-.07	1.06	**-.06**
Non-black Students	59	-.05	1.10	53	.49	.99	-.54	1.05	**-.52**

Summing Up Performance

- This group of 521 urban students from poor families are scoring 1 ½ to 2 years behind in math knowledge, the worst being fundamentals to Geometry.
- Ending the 5th grade (for most), they have skills comparable to beginning 4th graders or those finishing 3rd grade.
- In other words, from their 6 years of schooling, they are making 2/3 the progress.
- 12% of them are even further behind
- The neurocognitive assessments behave somewhat differently for very low scoring children.
  - They don't "see" number quickly
  - They respond too quickly to non-symbolic assessments, making more errors.

Early Math and Later Performance

- Early math absolute levels and growth in skills strongly predict 5th grade math outcomes, replicating the work of Watts et al. with a mixed income sample.
- Variations in components of early math relate to later outcomes as newer math research suggests they should even within this very low income sample.
- However, our data do not suggest that increasing math competencies though curricular intervention has the effects we would hope.
  - Possible explanation: the lack of congruence in the way Building Blocks taught children math and the math they have encountered in their 1st through 5th grades.

Other Interesting (unexplored) Findings

- Correlations between how children feel about math and how they rate their skills in math and their actual performance are all below .20.

- Correlations between teachers' ratings of children's math competencies and their actual skills average .55.

- Neither the students nor the teachers seem to be truly aware of how much the students have learned.

THANK YOU!
QUESTIONS?