The Misalignment of Kindergarten Mathematics Content

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Today's talk

- Motivation
- Prior research
- Our questions
- Data
- Methods
- Results
- Discussion/conclusion

Motivation: Early skills

- Early skills important for later school and life outcomes (e.g., Duncan et al., 2007; Farkas, 2003)
- Early may be best time to invest (e.g., Duncan & Magnuson, 2006; Doyle et al., 2009; Heckman, 2006)
- Academic skill gaps develop early (e.g., Fryer & Levitt, 2004, 2006; Reardon, 2011)

Motivation: Early math skills

- Early math skills most important for later school outcomes (Claessens, Duncan, & Engel, 2009; Claessens & Engel, 2013;Watts, Duncan, Siegler, & Davis-Kean, 2014; Wilson, 2014)
- Key advocacy groups (NAEYC, NCTM, NMAP) recent position statements highlight importance of mathematics education for ages 3 to 6
- K-12 STEM initiatives

The Changing Nature of Kindergarten

- Academicization (Bassok & Rorem, 2013)
  - Much more time reported on reading and mathematics in 2006/2010-11 compared with 1998-1999
  - Teacher expectations regarding both school readiness and what they will teach kindergarteners have changed as well
- Common Core State Standards for mathematics (CCSSM)
  - Adopted by many states in 2010 and full implementation in most (~43) by 2013-2014 or 2014-2015

Prior Research: Early math skills

- Foundational math skills predict both levels and gains in math achievement (Aunola et al., 2004; Bodovski & Farkas, 2007; Claessens, et al., 2009; Jordan et al., 2006, 2007, 2009; Watts, et al. 2014)
- Children who have difficulty counting have later difficulties in math (Geary et al., 1999)
- **The vast majority of children can count and know basic shapes at or prior to kindergarten entry** (Clements & Sarama, 2004; Engel, Claessens, & Finch, 2013; Mix et al., 2002; NRC, 2009)

Prior Research: Early math instruction

- Kindergarten teachers spent more time on reading in 1998-99
  - 5 hours/week on reading
  - 3 hours/week on math
- Kindergarten teachers cover basic content (Rudd et al., 2008)

Post-Kindergarten

- Teachers in grades 1-4 spend over 1/3 of instructional time on reading, about 1/6 on math (Morton & Dalton, 2007)

Early Childhood Education Emphasizes Reading

- Federal spending on reading initiatives over past decade (e.g., $6 billion on Reading First)
- Early childhood specializations/degrees in reading instruction
- Undergraduate programs in early childhood education underemphasize math; teachers of young children are unsure about teaching math (Ginsburg et al., 2008)

Theoretical Framework

- Development occurs through interaction of child with multiple contexts
- Children's skills and endowments influence and interact with contexts
- A child will develop more skill when the instruction/content is adapted to the child's ability
  - Child X instruction interactions in reading (Connor, Morrison, & Katch, 2004)

Interactions: Child X Instruction

- Research in reading finds that instruction just above a child's skill level produced larger gains in reading (Connnor et al., 2004, 2009)
- Theory of mathematics education (Sarama & Clements, 2009) suggests that children's existing math skills should be key determinants of what content they are taught next

Important interactions between math skills and content exposure

- The 5% of students who entered K not knowing basic numbers/shapes benefited from exposure to this content (Engel, Claessens, & Finch, 2013)
- Almost all students gain less when exposed to basic content, gain more from exposure to more advanced content (Claessens, Engel, & Curran, 2014)
  - This is true in both math and reading
  - For children from families with low income
  - Regardless of preschool experiences

Research Questions

1. What mathematics do children know at kindergarten entry (ECLS-K:1998)?
2. What content do kindergarten teachers focus on (ECLS-K:1998 & ECLS-K:2011)?
3. How does content exposure predict learning gains across kindergarten (ECLS-K:1998 & ECLS-K:2011?
4. What are the implications for the CCSSM kindergarten?

Data – Two nationally representative cohorts of kindergarteners

- Early Childhood Longitudinal Study—Kindergarten Cohorts (ECLS-K:1998) and (ECLS-K:2011)
  - Nationally representative samples of kindergartners in the 1998-99, and, more recently, 2010-11 school years
  - Data collected from parents, teachers, and schools
  - Direct assessments of achievement
  - Using data from fall and spring of kindergarten
    - Achievement assessments and teacher surveys about background and math content coverage/activities

Characteristics of Kindergarten Students

	ECLS-K:1998	ECLS-K:2011
In full day K	.55	.83
Female	.49	.49
Race/Ethnicity		
White	.59	.52
Black	.15	.13
Hispanic	.18	.25
Asian	.03	.04
Age	68.46	68.52
Single parent	.22	.22
English not primary home language	.12	.17
Observations	17,810	15,090

Kindergarten Teacher Characteristics

	ECLS-K:1998	ECLS-K:2011
Female	.98	.98
Race/Ethnicity		
White	.86	.83
Black	.07	.06
Hispanic	.04	.08
Asian	.02	.02
Master's degree or higher	.37	.46
Years teaching K	9.07	8.79
Certified	.89	.89
Observations	3,020	3,060

Measures

- Math Achievement Test Score
  - Outcome measured at Spring K
- Kindergarten Math Content
  - Teacher survey report of math content coverage
- Controls
  - School-entry test scores (reading, math)
  - Teacher report of attention skills
  - Child characteristics
  - Family background
  - Teacher and classroom information

Math Test Proficiency Levels (provided by NCES, but only for 1998-99)

Mathematics Test Proficiencies	Skills Measured
Proficiency Level 1	One-digit numerals, geometric shapes, and one-to-one counting up to ten
Proficiency Level 2	All one-digit numerals, counting beyond ten, patterns, and using nonstandard units of length
Proficiency Level 3	Two-digit numerals, sequence, ordinal position, and simple word problem
Proficiency Level 4	Simple addition and subtraction problems
Proficiency Level 5	Multiplication and division problems and more complex number patterns
Proficiency Level 6	Place value
Proficiency Level 7	Rate and measurement
Proficiency Level 8	Fractions
Proficiency Level 9	Area and volume

Teacher content measures

Teacher Content Measures	ECLS-K:1998 α	ECLS-K: 2011 α	Teacher Survey Items
1. Basic counting & shapes	.59	.58	Count out loud; Work with geometric manipulatives; Correspondence between number and quantity; Recognize & name geometric shapes (4 items)
2. Patterns & measurement	.77	.77	Work with rulers & measuring instruments; Identify relative quantity, Sort objects by rule; Order objects by size or other property; Make or extend patterns (5 items)
3. Place value & currency	.59	.58	Recognize value of coins and currency; Place value; Read two-digit numbers; Ordinal numbers (4 items)
4. Addition & subtraction	.88	.85	Add & subtract single-digit numbers (2 items)

Used categories measured on ECLS-K math test (1998-99 only) to create content coverage measures aligned with content students are tested on

Method

OLS model:

$$Math_{iSK} = a_1 + ß_1 Content_{iK} + ß_2 Math_{iFK} + ß_4 Reading_{iFK} + ß_5 GenKnow_{iFK} + ß_6 Child_{iFK} + ß_7 Fam_{iFK} + ß_8 Teacher_{iK} + ß_9 Class_{iK} + \varepsilon_i$$

- **Content=set of math content areas covered in child i's classroom**
- **Includes fall of kindergarten math test, reading test, attention skills, and teacher/classroom, child and family background controls**

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- **Content=set of math content areas covered in child i's classroom**
- **Includes fall of kindergarten math test, reading test, general knowledge, attention skills, and teacher/classroom, child and family background controls**

Descriptive results ECLS-K:1998 (from Engel, Claessens & Finch, 2013)

Student Math Proficiency Levels	Rate of Mastery by Fall K	Content Measures	Mean Days/Month	SD
Level 1	95%	Basic Counting & Shapes	12.70	4.11
Level 2	62%	Patterns & Measurement	7.68	4.44
Level 3	25%	Place value & Currency	8.61	5.12
Level 4	7%	Addition & Subtraction	4.38	4.07

Students

Teachers

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Note: Addition and subtraction descriptives shown here include 4 items two items asking about addition with double digits and subtraction with double digits were not included in the ECLS-K:2011. The cross cohort comparison measures include only the 2 items.

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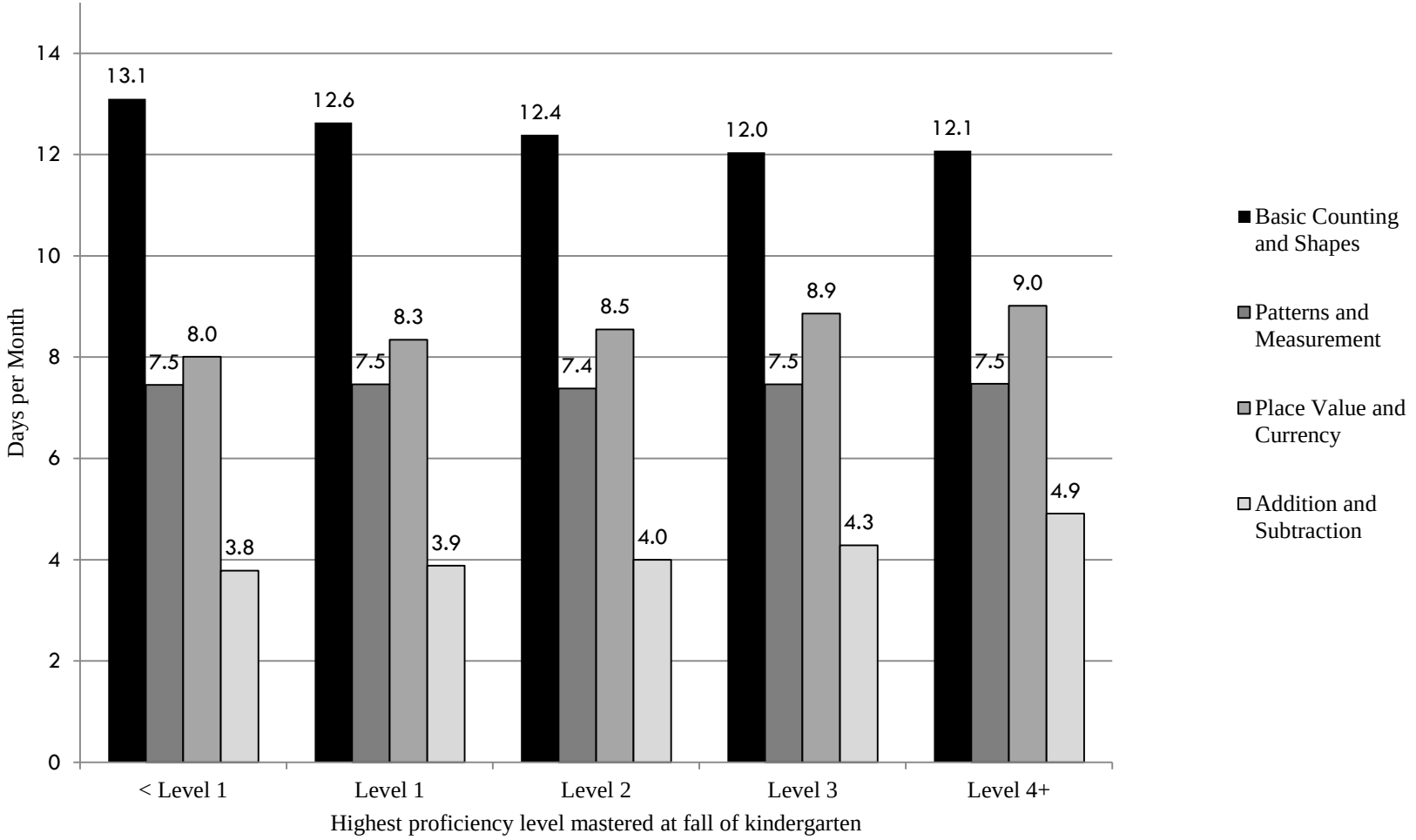
Average teacher reported content coverage by highest proficiency level sample students have mastered at kindergarten entry



Descriptive results

Content Measures	ECLS-K: 1998	ECLS-K: 2011	Difference
Basic Counting & Shapes (4 items)	12.61 (4.03)	12.81 (3.97)	.2*
Patterns & Measurement (5 items)	7.45 (4.35)	7.68 (4.43)	.23
Place value & Currency (4 items)	8.48 (5.11)	10.59 (5.22)	2.11**
Addition & Subtraction (2 item measure)	7.50 (6.46)	9.45 (6.47)	1.95***

*p<.05, **p<.01, ***p<.001

Teacher Content Measures Predicting Spring of K Math Achievement

Teacher Content Measures:	**Spring K Math Test Score**							
	1998	2011	1998	2011	1998	2011	1998	2011
Basic counting & shapes	-.018*** (.005)	-.004 (.006)						
Patterns & measurement			-.006 (.005)	.001 (.006)				
Place value & currency					.034*** (.005)	.043*** (.006)		
Addition & subtraction							.038*** (.005)	.048*** (.006)
Observations	17,810	15,090	17,810	15,090	17,810	15,090	17,810	15,090

* $p < .05$, ** $p < .01$, *** $p < .001$; all models have full set controls including fall K test scores, child, family, teacher, classroom controls; standard errors adjusted for sample-design clustering

Teacher Content Measures Predicting Spring of K Math Achievement

Teacher Content Measures	Spring K Math Test Score	
	1998	2011
Basic counting & shapes	-.031*** (.006)	-.023** (.007)
Patterns & measurement	-.015* (.006)	-.020** (.009)
Place value & currency	.035*** (.009)	.042*** (.008)
Addition & subtraction	.037*** (.009)	.046** (.008)
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Kindergarten Content and Common Core

Common Core State Standards for Mathematics

- Kindergarten Domains
  - Counting and Cardinality
  - Operations and Algebraic Thinking
  - Number & Operations in Base Ten
  - Measurement & Data
  - Geometry

Kindergarten Content and Common Core

Common Core State Standards for Mathematics

- Kindergarten Domains
  - Counting and Cardinality
    - Know number names and the count sequence
    - Count to tell the number of objects
    - Compare Numbers
  - Operations and Algebraic Thinking
  - Number & Operations in Base Ten
  - Measurement & Data
  - Geometry

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Standards in this domain:

CCSS.MATH.CONTENT.K.CC.A.1	CCSS.MATH.CONTENT.K.CC.A.2	CCSS.MATH.CONTENT.K.CC.A.3
CCSS.MATH.CONTENT.K.CC.B.4	CCSS.MATH.CONTENT.K.CC.B.5	CCSS.MATH.CONTENT.K.CC.C.6
CCSS.MATH.CONTENT.K.CC.C.7		

Know number names and the count sequence.

CCSS.MATH.CONTENT.K.CC.A.1

Count to 100 by ones and by tens.

CCSS.MATH.CONTENT.K.CC.A.2

Count forward beginning from a given number within the known sequence (instead of having to begin at 1).

CCSS.MATH.CONTENT.K.CC.A.3

Write numbers from 0 to 20. Represent a number of objects with a written numeral 0-20 (with 0 representing a count of no objects).

Count to tell the number of objects.

CCSS.MATH.CONTENT.K.CC.B.4

Understand the relationship between numbers and quantities; connect counting to cardinality.

CCSS.MATH.CONTENT.K.CC.B.4.A

When counting objects, say the number names in the standard order, pairing each object with one and only one number name and each number name with one and

Creating Common Core Measures

Common Core Domain (# of items)	ECLSK: 1998	ECLS-K: 2011	Difference	Alignment measures (# of items)
Counting and Cardinality (5)	11.2 α=.60	12.7 α=.60	1.5***	**Basic Counting** & Shapes (2)
Operations & Algebraic Thinking (2)	7.5 α=.88	9.45 α=.85	1.95***	Addition & Subtraction (2)
Numbers & Operations in Base 10 (2)	9.74 α=.78	12.47 α=.79	2.73***	Place Value & Currency (2)
Measurement & Data (3)	7.94 α=.57	8.32 α=.56	.38*	Patterns & Measurement (2)
Geometry (2)	9.11 α=.51	8.81 α=.59	-.30*	Basic Counting & **Shapes** (2)

* $p < .05$ ** $p < .01$ *** $p < .001$

Common Core Measure Results

Teacher Content Measures	**Spring K Math Test Score**			
	1998	2011	1998	2011
Misalignment Categories				
Basic counting & shapes	-.031***	-.023**		
Patterns & measurement	-.015*	-.020**		
Place value & currency	.035***	.042***		
Addition & subtraction	.037***	.046**		
Common Core Categories				
Counting and Cardinality			.013*	.019**
Operations and Algebraic Thinking			.036***	.044***
Numbers in Base Ten			.020***	.028***
Measurement and Data			-.011	-.005
Geometry			-.027***	-.040***
Observations	17,810	15,090	17,810	15,090

Results Summary

- The vast majority of children (~95% in 1998-1999) enter kindergarten having mastered basic counting & shapes
- Teachers spend the most time, 13 days/month, on basic counting & shapes
- Basic counting & shapes is negatively associated with math achievement across kindergarten, on average, but time on place value & currency, addition & subtraction is positive
- Reported time on more 'advanced content' has increased between 1998 and 2011, but no change in time on most basic content
- Implications of CCSSM for shifting mathematics content/improving alignment unclear, potentially positive?

Promoting early math skills

- Many kindergarteners spend a substantial part of their limited time on mathematics being exposed to content they have already mastered
  - This additional exposure may be detrimental

Limitations

- Data are observational
- Small effects—~5 additional days/month reported on addition & subtraction associated with .04 standard deviation increase in spring K math test scores
- Content Measures
  - Teacher survey reports
  - Not designed to measure Common Core alignment
- Data are limited (don't have math skills for entire class)

Implications

- Kindergarten teachers may not be focusing on the 'right' mathematics content for many children
  - May be due to:
    - Standards/curricula focus on wrong content
    - Lack of knowledge about children's skills (no assessment at K entry?)
    - Discomfort/lack of pedagogical knowledge for teaching more advanced content
- Small effects, but…
  - Content might be easily changed
  - Could potentially be a cost effective avenue for improving early math learning

Predicting content w/Fall K math (ECLS-K:1998)

	Basic Counting and Shapes		Patterns and Measurement		Place Value and Currency		Addition and Subtraction	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fall of Kindergarten								
Math Achievement Test Score	-0.032		-0.0093		0.023		0.034*	
	(0.021)		(0.016)		(0.017)		(0.018)	
Teacher Rated Math Achievement		0.061*		0.090**		0.072**		-0.00058
		(0.035)		(0.035)		(0.030)		(0.034)
Observations	11,517	7,734	11,517	7,734	11,517	7,734	11,517	7,734
R-squared	0.133	0.133	0.103	0.103	0.074	0.086	0.110	0.117

Note. All models are weighted. Robust standard errors, clustered by school, in parentheses. Outcome measure is standardized. All continuous independent variables shown are standardized. All models include child, family, teacher, and classroom controls.

*** p<0.01, ** p<0.05, * p<0.1

Why not school f.e.?

- Meaningful variation in content coverage more likely to occur across rather than within schools (within schools often use same curriculum, textbook)
- Concerned that variation in school fixed effect models likely to be spurious
- Limited by # of classrooms per school – mean of 2.5, 60% of schools have 1 or 2 classrooms in ECLS-K:1998

Teacher Content Measures Predicting Spring of K Math Achievement

Teacher Content Measures	**Spring K Math Test Score**			
	1998	2011	1998	2011
Basic counting & shapes	-.031*** (.006)	-.023** (.007)	-010 (.009)	-.021* (.009)
Patterns & measurement	-.015* (.006)	-.020** (.009)	-.006 (.008)	.002 (.009)
Place value & currency	.035*** (.009)	.042*** (.008)	.016 (.008)	.029*** (.009)
Addition & subtraction	.037*** (.009)	.046** (.008)	.019* (.008)	.012 (.008)
School Fixed Effects			X	X
Observations	17,810	15,090	17,810	15,090

* $p < .05$, ** $p < .01$, *** $p < .001$; all models have full set controls including fall K test scores, child, family, teacher, classroom characteristics; standard errors adjusted for sample-design clustering

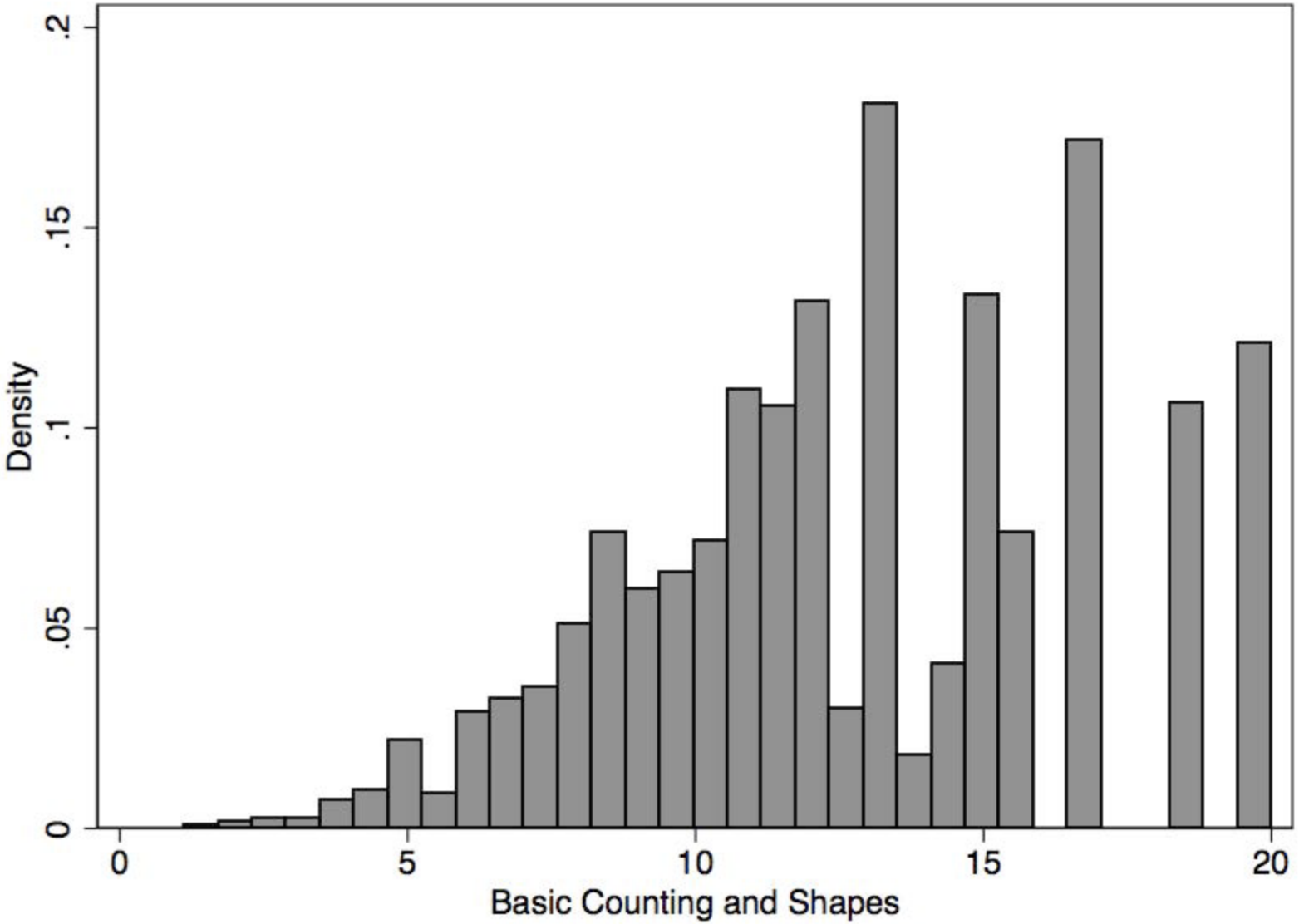
Correlations Among Content Measures

	Basic Counting & Shapes	Patterns & Measurement	Place Value & Currency	Addition & Subtraction
Basic Counting & Shapes	1			
Patterns & Measurement	.60	1		
Place Value & Currency	.36	.43	1	
Addition & Subtraction	.30	.36	.44	1

Teacher Content Measures Predicting Spring of K Reading Achievement

Teacher Content Measures	Spring K Reading Test Score	
Letter Recognition	-0.034** (.009)	-0.033** (.010)
Beginning & Ending Sounds	0.028** (.083)	0.026** (.083)
Sight Words	0.017 (.009)	0.015 (.009)
Comprehension	0.051** (.009)	0.043** (.009)

n=11,517 students, **p<.01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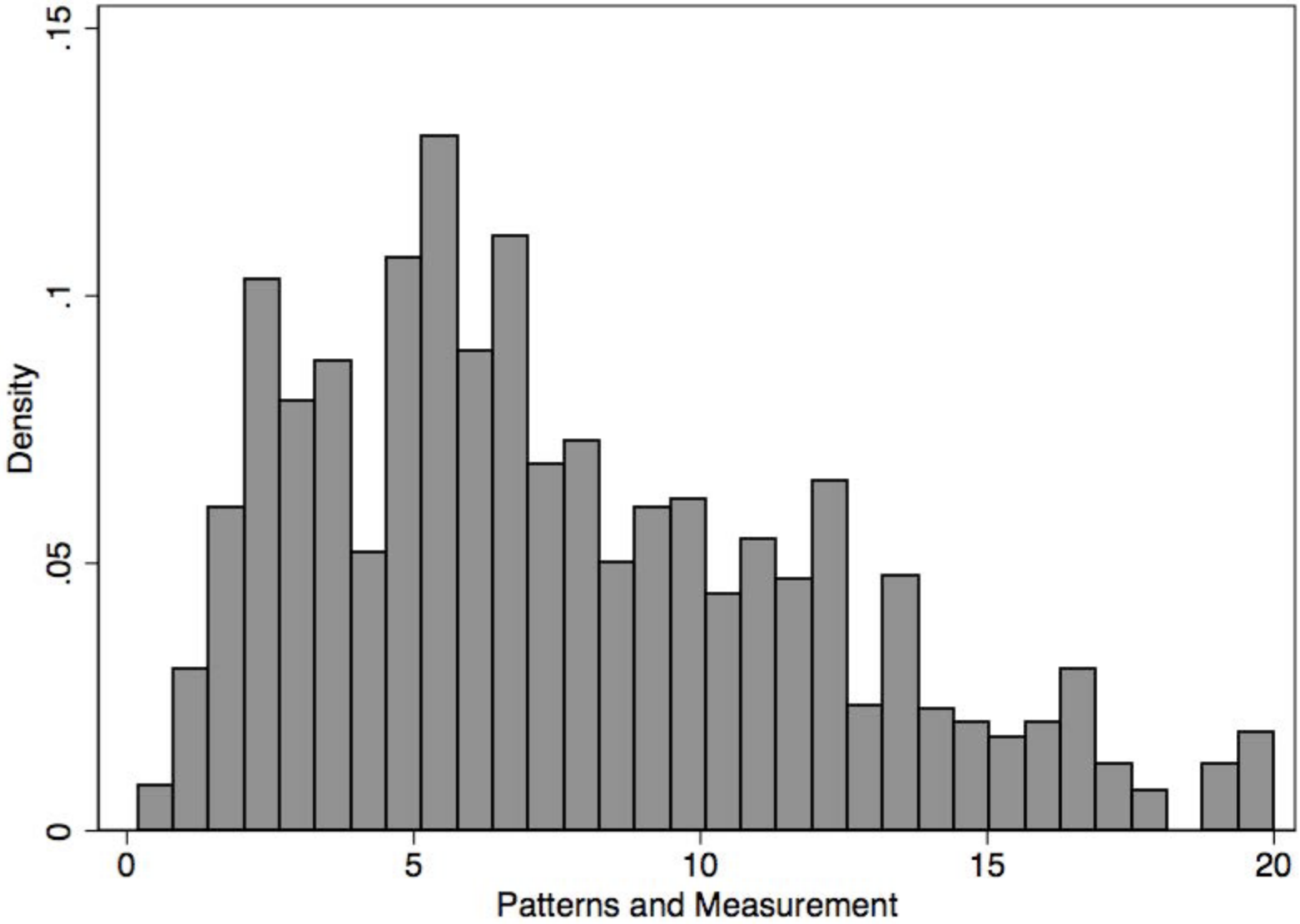
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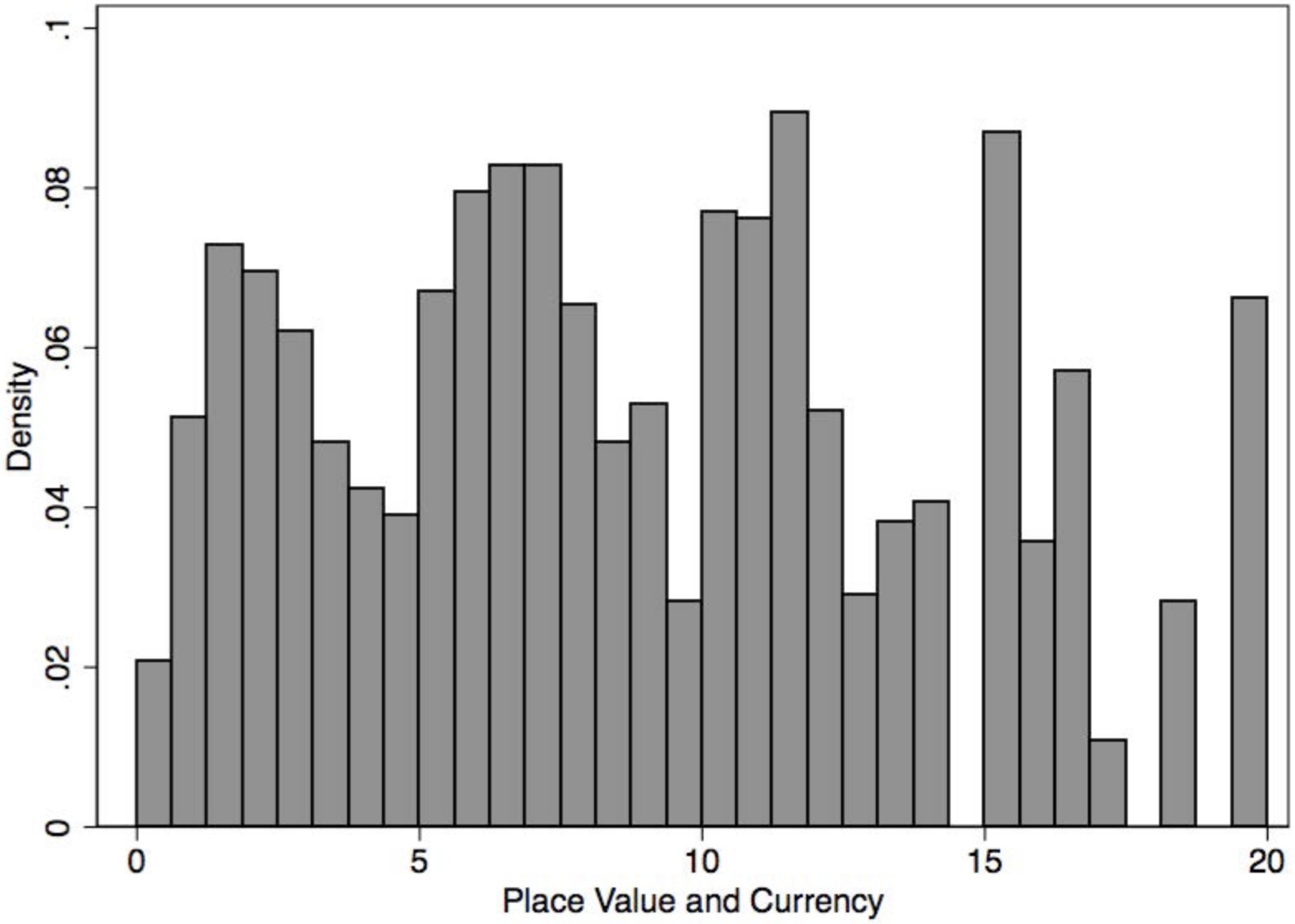
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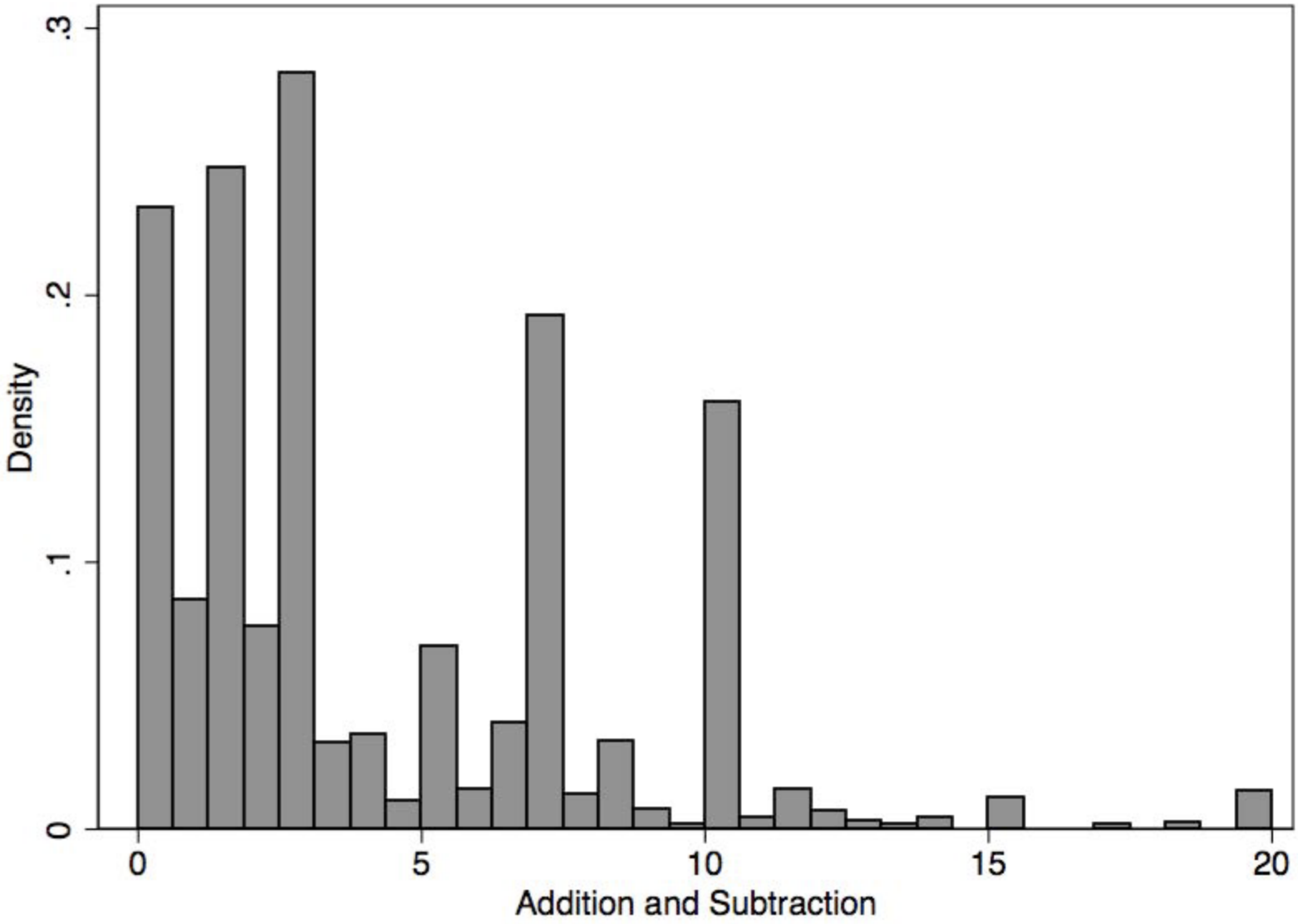
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Teacher Content Measures Predicting Spring K Math Achievement by Fall K Math Proficiency

	Highest proficiency level mastered				
Teacher Content Measures:	<Level1	Level 1	Level 2	Level 3	Level 4+
Basic counting & shapes[a]	.052* (.025)	-.032* (.013)	-.042** (.012)	-.034 (.020)	-.039 (.071)
Patterns & measurement[b]	-.067* (.026)	-.015 (.012)	-.001 (.011)	-.037 (.021)	-.064 (.071)
Place value & currency[c]	.019 (.024)	.044** (.012)	.023 (.012)	.035 (.018)	.071 (.064)
Addition & subtraction	.011 (.025)	.013 (.012)	.040** (.011)	.059** (.017)	.055 (.048)
Controls	X	X	X	X	X
Observations	553	3613	4345	2175	494

**p<.01, *p<.05

[a]coef. for <Lev. 1 sig. dif. from coef. for Lev. 1, Lev. 2, Lev. 3

[b]coef. for <Lev 1 sig. dif. from coef. for Lev. 2

[c]coef for Lev. 1 sig. dif. from coef. for Lev. 3

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