THE IMPACT OF INQUIRY-BASED MATHEMATICS ON STUDENT ACHIEVEMENT

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The Mathematical Education of Teachers

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Greater Birmingham Mathematics Partnership

Partner	Students	Minority	Red. Lunch
Bessemer City Schools	4,087	97%	82%
Fairfield City Schools	2,323	100%	71%
Homewood City Schools	3,552	34%	22%
Hoover City Schools	11,141	22%	13%
Jefferson County Schools	32,553	28%	31%
Mt. Brook City Schools	4,150	1%	0%
Shelby County Schools	22,759	16%	24%
Trussville City Schools	4,100	8%	11%
Vestavia Hills City Schools	5,226	6%	4%
University of Alabama at Birmingham	17,584	31%	
Birmingham-Southern College	1,412	16%	
Mathematics Education Collaborative			

Summer Courses

Total enrollment over 1700

- *Patterns: The Foundations of Algebraic Reasoning*
- *Patterns II*
- *Numerical Reasoning*
- *Geometry and Proportional Reasoning*
- *Probability*
- *Extending Algebraic Reasoning*
- *Extending Algebraic Reasoning II*

Challenging Courses and Curricula

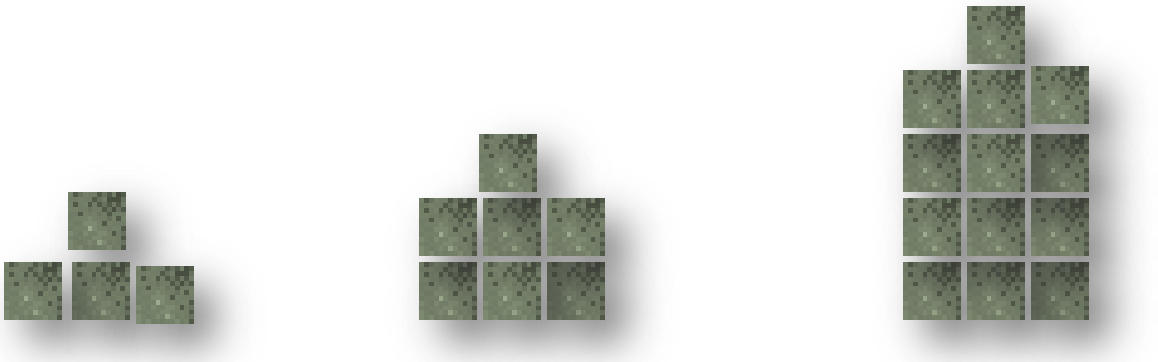
- Big mathematical ideas
- Inquiry and reflection
- Productive disposition
- Communication

Objective Test: *Patterns*

- 31 items pre and post
- Content Knowledge for Teaching Mathematics (CKTM) plus additional items developed by Nanette Seago

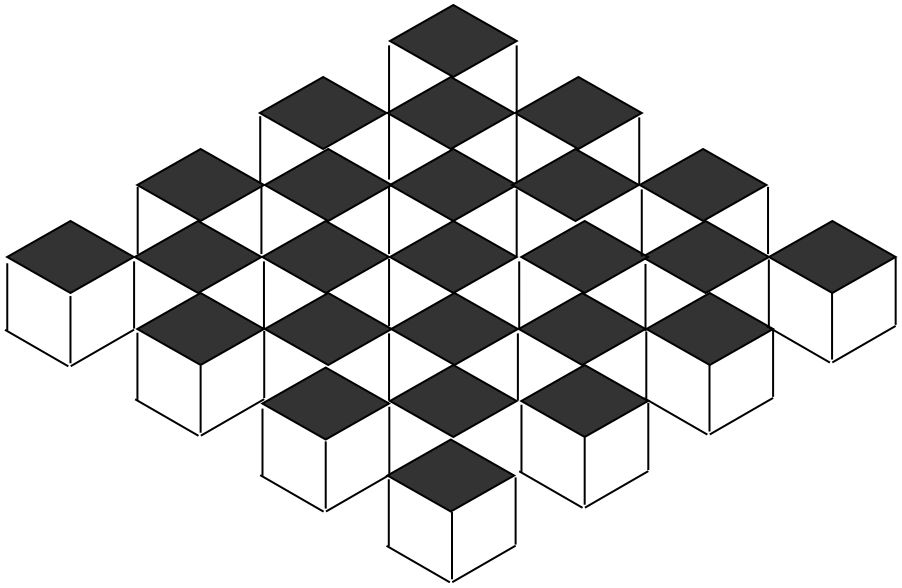
- 3-point increase in mean ($N = 76$)
- Effect size = 0.5; medium effect
- Preliminary longitudinal data (N=20) indicates gains are maintained

Sample *Patterns* Task 1

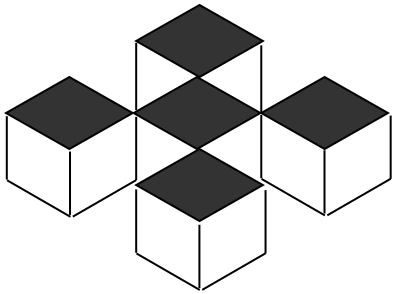


- Build two more steps in this pattern.
- How many tiles are needed for the 10^{th} step?
- How many tiles are needed for the n^{th} step?

Sample *Patterns* Task 2



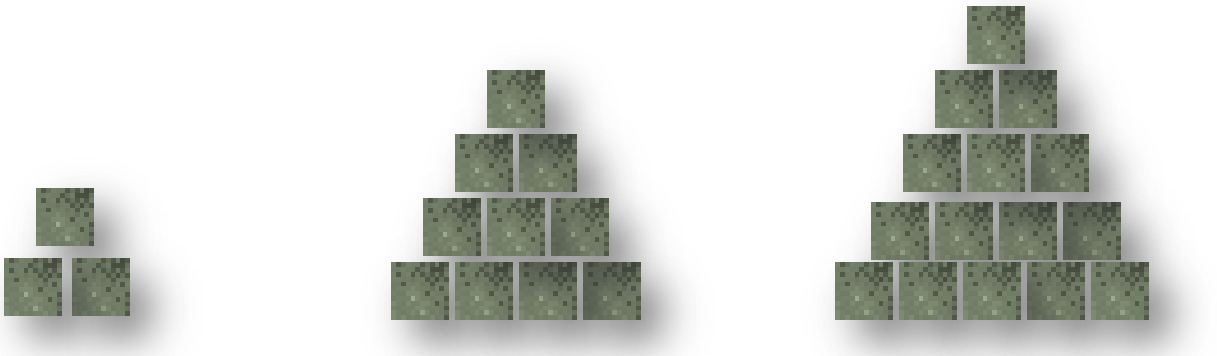
Step 4



Step 2

- Build two more steps in this pattern.
- How many cubes will it take to build the 10^{th} step?
- How many cubes will it take to build the n^{th} step?
- Explain why your answers make sense geometrically.

Sample *Patterns* Task 3



Step 2 Step 4 Step 5

- Build two more steps in this pattern.
- How many tiles are needed for the 10^{th} step?
- How many tiles are needed for the n^{th} step
- Explain why your answers make sense geometrically.

Performance Assessment: *Patterns*

- Scored with Oregon Department of Education Rubric
- Two raters; high inter-rater reliability
- A Wilcoxon signed ranked test showed statistically significant improvement

Patterns ***N* = 70**	**Conceptual Understanding**		**Processes and Strategies**		**Communication**		**Accuracy**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Median	2.0	4.0	2.0	4.0	2.0	4.0	4.0	5.0

ODE Rubric Descriptors

- Descriptors for performance at the 2.0 level:
  - Underdeveloped, sketchy, ineffective, and unclear
- Descriptors for performance at the 4.0 level:,
  - complete, adequate, relevant, explained, and supporting the solution
- Inter-rater reliability over .7 on each dimension

Portfolios: Patterns

- Scored with CEA-developed rubric
- Three raters; consensus-reaching

Patterns (*N* = 20)	Median Score	Incomplete Score = 1	Emerging Score = 2	Proficient Score = 3	Expert Score = 4
Problem Translation	3	0	1	12	7
Mathematical Procedures	3	0	1	13	6
Productive Disposition	3	0	1	11	8
Inquiry and Reflection	3	0	2	11	7
Justification and Communication	3	0	2	11	7

Behavioral Checklist: Patterns

- CEA-developed checklist based on CCC dimensions

Patterns (*N* = 15)	Day 1	Day 4	Day 8
Mathematical Ideas			
uses variables to describe unknowns	7%	27%	93%
explains why equations make sense geometrically	7%	27%	73%
represents linear, quadratic functions in variety of ways	0%	13%	53%
Productive Disposition			
persists when answer is not known	0%	33%	87%
asks for guidance but not answers	13%	27%	80%
tries variety of strategies for approaching problems	13%	73%	93%

Behavioral Checklist: Patterns

Patterns (*N* = 15)	Day 1	Day 4	Day 8
Inquiry and Reflection			
makes extensions and connections beyond problem	0%	13%	67%
explores why it works, whether it will always work	0%	7%	53%
confusion and mistakes lead to further exploration	20%	73%	100%
Communication			
explains reasoning fluently	0%	13%	80%
asks probing questions	20%	33%	93%
shares ideas with class	27%	47%	93%

Classroom Observations

- Reformed Teaching Observation Protocol (RTOP) --- Two raters; consensus-reaching

RTOP Subscale (maximum of 20)	Courses	Median
Lesson Design/Implementation	0 1 2 3+	5 12 14 13
Communicative Interaction	0 1 2 3+	4 11 13 13

Sample (N = 116); 0 courses (N=17); 1 course (N=35); 2 courses (N=38); 3+ courses (N=26)

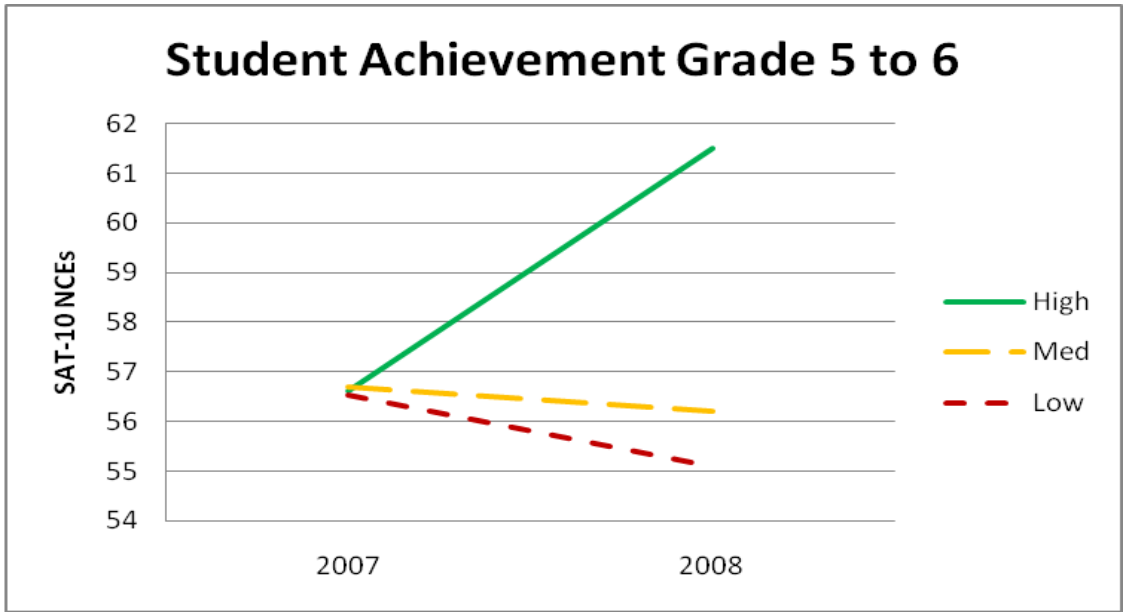
Classroom Observations

RTOP Subscale (maximum of 20)	Courses	Median
Procedural Knowledge	0 1 2 3+	7 11 14 13
Propositional Knowledge	0 1 2 3+	7 12 14 15
Student/Teacher Relationships	0 1 2 3+	7 14 15 15

Ranking of Implementation of Inquiry-Based Pedagogy

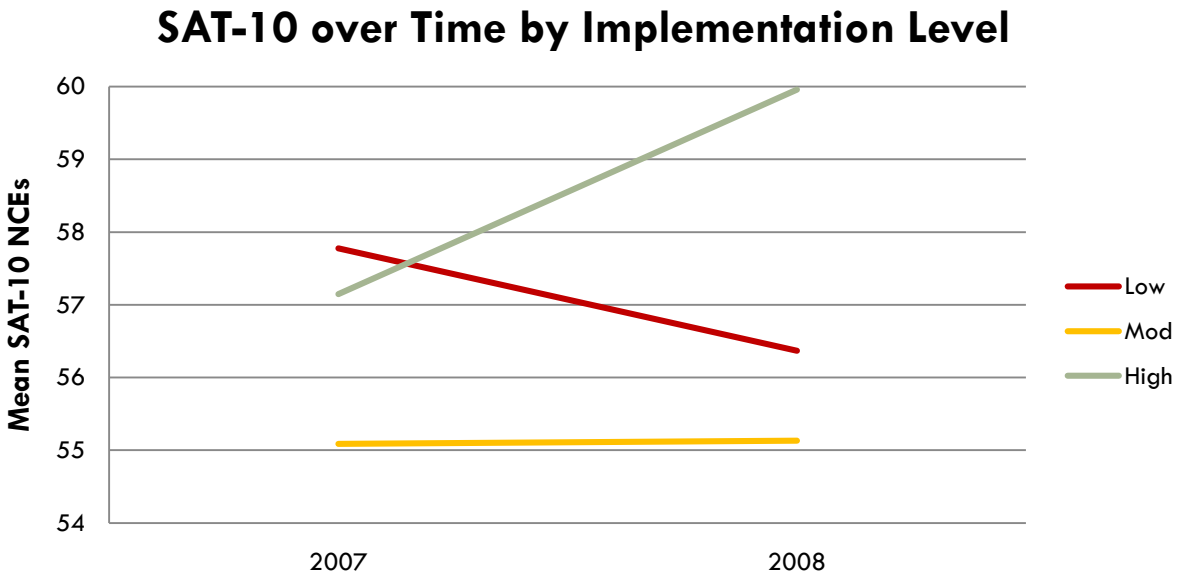
- High implementing grade level
  - At least one summer course by every teacher
  - At least 30% RTOPed, and all scored at 12.5 or above on every subsection of RTOP
- Low implementing
  - No participation, or
  - Participation as above, 30% or more RTOPed, and all scored at 5 or below on each subsection of RTOP
- Moderate implementing
  - All others

Student Achievement by Implementation



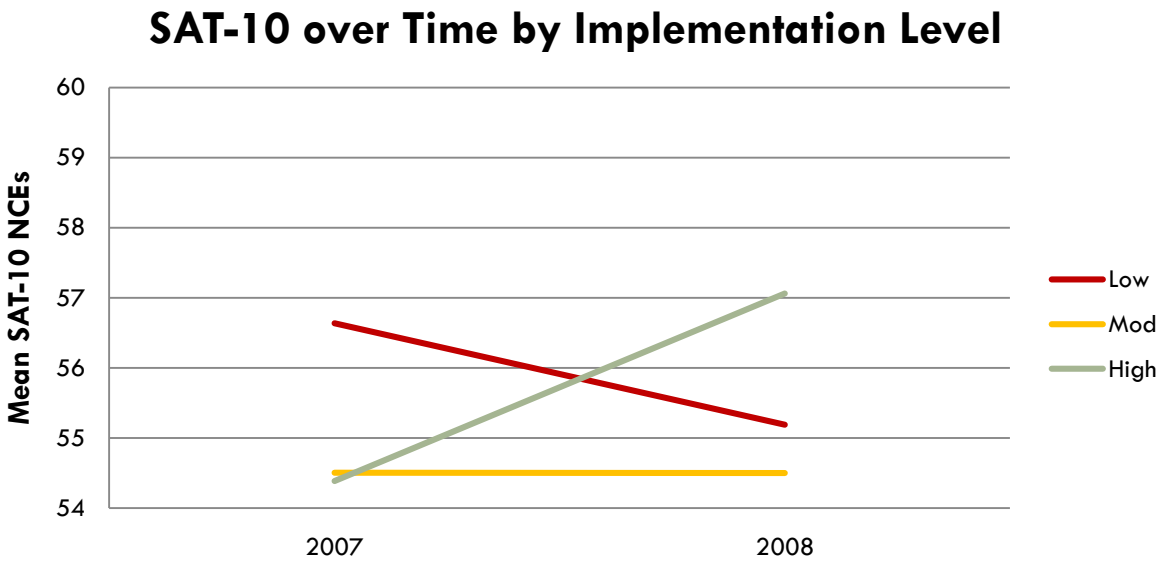
Implementation Level	2007 Mean	Std Dev	2008 Mean	Std Dev	*N*
Low	56.5	20.7	55.1	19.6	3640
Moderate	56.7	21.5	56.2	20.7	1652
High	56.6	23.6	61.5	22.1	666
Total (6 systems)	56.6	21.3	56.1	20.3	5958

Student Achievement Grades 5-8



Implementation Level	2007 Mean	Std Dev	2008 Mean	Std Dev	*N*
Low	57.8	20.8	56.4	20.9	14506
Moderate	55.1	20.8	55.1	20.9	6215
High	57.1	21.1	60.0	21.0	3305
Total (6 systems)	57.0	20.9	56.5	21.0	24026

SAT-10 Excluding High SES System



Implementation Level	2007 Mean	Std Dev	2008 Mean	Std Dev	N
Low	56.6	20.4	55.2	20.4	13811
Moderate	54.5	20.6	54.5	20.6	6070
High	54.4	20.4	57.1	20.2	2886
Total (5 systems)	55.8	20.5	55.3	20.4	22767

Statistical Significance

- Methods for analysis
  - Repeated Measures ANOVA
  - Calculation of Difference Score and Univariate Analysis
  - Both significant at $p < .05$
  - Adjusted for differences in sample size

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Operational Definition of Challenging Courses and Curricula

- **Big Mathematical Ideas**
  - Teach for understanding. This refers to helping students achieve "an integrated and functional grasp of mathematical ideas." [NRC] This includes developing conceptual understanding, strategic competence, and procedural fluency.
  - Introduce a mathematical idea by posing problems that motivate it.
  - Provide a coherent collection of problems organized around a big mathematical idea.
  - Provide opportunities for students to use multiple representations of a mathematical idea.
  - Provide opportunities for students to explore real-world problems connected to big mathematical ideas.
- **Inquiry and Reflection**
  - Engage students in inquiry.
  - Communicate that learning mathematics should be a sense-making process.
  - Ask students to justify their thinking.
  - Ask students to engage in reflection.
  - Encourage students to think critically about mathematical ideas and solutions.
  - Encourage diverse ways of thinking.
  - Communicate that both accuracy and efficiency are important.
  - Incorporate technology when appropriate.
- **Productive Disposition**
  - Help students develop persistence, resourcefulness and confidence.
  - Help students become autonomous learners.
  - Provide a safe, respectful learning environment.
- **Communication**
  - Promote the development of mathematical language.
  - Value written communication by asking students to explain their ideas in writing.
  - Value verbal communication by asking individuals and groups to articulate their thinking.
  - Value the role of communication in developing intellectual community in the classroom.
  - Establish clear expectations for mathematical assignments.