The Design & Findings of a Random-Controlled Trial of a Game-Based Successful Mathematics Intervention

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Math Snacks materials were developed with support from the National Science Foundation (0918794). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
Today, we’ll:

1. Briefly share findings
2. Review the research-design process (interactive workshop)
   a) Needs analysis including pre-design research
   b) Establish learning goals
   c) Game design
   d) Pilot studies and instrument validation
3. Group Discussion
Beginning with the Final Study

• Research Design

Experimental study measuring the effect of four educational games and related inquiry-based activities on students’ understandings of ratios, coordinate plane, and number systems (fractions and decimals)

• 48 classrooms randomly assigned to Group A or Group B

• All classrooms were fifth grade in one district (75% Hispanic, 24% White)

• Math Gains measured on Mathematics Learning II (reliability .89)

• Observations of classrooms (twice per teacher by 2 observers)
Theoretical Framework - Math Snacks

• Theoretical Framework - constructivist learning principles for building knowledge (Scardamalia & Bereiter, 2008; problem-based approach has been described as anchored instruction (Alessi & Trollip, 2001; Moreno, 2010; Affordances of games for concept images and learning (Tall and Vinner; J. Gee, Keith Devlin); Additional activities to apply knowledge learned from games. Use of useful common core. Research on pivot points (Stanford).
Math Snacks Intervention Model

Each lesson protocol included:

– game play session with group discussion (30-40 minutes),

– hands-on activity related to game play (30-40 minutes),

– second game-play session with a final discussion (30-40 minutes)

– optional out-of-school game play – 93% of students engaged in game play out of school

Observations of classroom teaching and game playing (2 times per teacher, trained observers)
Research Questions

1. Will students who were taught using the *Math Snacks Intervention* (A) show greater growth in mathematical knowledge (ratios, coordinate plane, and fractions, decimals) than students taught mathematics using only the reg. district curriculum (B)?

2. Will students who received the delayed five-week intervention (B) have equivalent math knowledge gains as students (A) who received the first five-week intervention?

3. Were initial gains by Group A sustained?
Scores on **Measure of Mathematics Learning II**

(Group A n=361, Group B n=380)

*Math Snacks* introduced to Group A after Test 1

Group B continued with **regular instruction**
Scores on *Measure of Mathematics Learning II*

(Group A n=361, Group B n=380)

- **Math Snacks** introduced to Group A after Test 1
- **Math Snacks** introduced to Group B after Test 2
### Timeline for Delayed Treatment Model

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
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<tbody>
<tr>
<td>Group A</td>
<td>Math Snacks with district math curriculum</td>
<td>District math curriculum</td>
</tr>
<tr>
<td>Group B</td>
<td>District math curriculum</td>
<td>Math Snacks with district math curriculum</td>
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### Mean Scores on Measure of Mathematics Learning II

<table>
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<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
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<tr>
<td></td>
<td>Mean</td>
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<tr>
<td></td>
<td>on</td>
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<tr>
<td>Test 1</td>
<td>23.64</td>
<td>28.91</td>
<td>31.58</td>
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<tr>
<td></td>
<td>(8.47)</td>
<td>(8.77)</td>
<td>(8.80)</td>
</tr>
<tr>
<td></td>
<td>Significant gain</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>$p &lt; .001$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td>26.37</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(8.71)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 3</td>
<td>31.10</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(8.43)</td>
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**Groups:**
- **Group A:** $n = 361$
- **Group B:** $n = 380$

**Significant gain:**

$p < .001$
Pre-Math Snacks Research

• Pre-design Research- Using 24,000 standardized tests with open-ended items, 500 hours of classroom observation, and additional documentation of areas teachers find mathematically challenging lead to the mathematical goals for Math Snacks.

Karin Wiburg and Ken Korn (2008 and 2011)
Same Troubles Year after Year (Wiburg & Korn)

Numerical Concepts & Mathematical Operations

- District A
- District B
- District C
- District D

Common low scores: B4- Proportional Thinking, B5- Operations with fractions and decimals, C1- estimation, C4- Interpret and Use Ratios  2008 data
Start with Needs

Define Outcomes

– What does it look like if user understands?

– How is it currently taught?

  • What works?

  • What doesn’t?

In order to establish math goals, the Math Snacks team evaluated standardized test results for 6th and 7th graders so identify mathematical understanding. Additionally, the team used interviews with teachers and students and classroom observation to tease the gaps into needed goals for learning. Those goals were then prioritized so that the concepts with the most "mathematical mileage" are highlighted as those most relevant for the 6th and 7th grade learners.

The Math Snacks team uses these goals and concepts as a starting point for development, creating animations, games and interactive tasks that give learners a conceptual understanding of mathematics by applying knowledge in ways that demonstrate this understanding. The goals and outcomes are interrelated. The team will not create one module per concept, but will use the knowledge of gaps-based learning to create visually stimulating content that illustrates the different concepts and the connections between them.

**Overarching Goal:**

Help middle school learners understand the concepts behind traditionally misunderstood mathematical content by:

1. Encouraging multiple and visual representations of numbers and operations. Numbers should always include whole numbers, fractions, mixed numbers, and decimals. Operations include addition, subtraction, multiplication, and division.

2. Providing concrete situations in which numbers and operations are used.

3. Demonstrating understanding of concepts through applications using numbers and operations.

**Content:** Based on their understanding of the concepts, learners will be able to:

1. **Number Sense**
   - A. Given visual representations of (draw pictures of) whole numbers, fractions, and decimals.
   - B. Provide context for the usefulness of fractions and decimals.
   - C. Decompose numbers in different ways and use three decompositions to solve problems in various contexts.
     - i. e.g., 8 - 5 + 3 - 4 = 10 - 2 = 7, 6 = 5
   - D. Demonstrate facility with the base ten system for representation of numbers, such as the thousands, hundreds, and tens places, as well as the thousands, hundreds, and tens places.
     - i. Explain differences between 003.34 and 00.34.

2. **Operations**
   - A. Provide visual representations of the four operations, especially on the number line.
     - i. e.g., draw a picture of what it means to multiply 6x10 or 6.5 x 10 on a number line.
   - B. Demonstrate or give examples of how the operations on fractions and decimals follow directly from the operations on whole numbers.
   - C. Use visual representations and contextual situations to demonstrate the similarities and differences between operations. For example:
     - i. the inverse relationship between addition and subtraction (they undo each other),
     - ii. the inverse relationship between multiplication and division (they undo each other),
     - iii. the distributive relationship between multiplication and addition/ subtraction (7 times 215 is the same as 7 times 200 plus 7 times 15 or 7215 ÷ 7 = 200 + 15).
   - D. Create the appropriate operation for a given situation.
Make a Tool

Brainstorm

– Animation? Game?
– What does the learner do?
  • Inquire?
  • Memorize?
  • Explore?
  • Experiment?

Wiburg • Barbara Chamberlin
Learning Games Design Model  
*(this is a whole process)*

Assessment Measures

• **Measure of Mathematics Learning II**
  Released Items from the NAEP modified after trials

• **OLE2- Observation of Learning Environments**

• **Self-efficacy**

• **Embedded gameplay data especially for out-of-school learning**
Small group activities

• Possibilities for pilot testing of new game or animation.
• What kind of instruments are needed to gather the data you want?
What have you learned?

• What are you measuring? (not just content)
• Encouraging inquiry-based learning
Large Pilot testing Spring 2013

Keys to Success:
• Pilot testing of product and tools  
  – With learners, teachers, in classrooms  
• Extensive review of teacher use  
• Observers in classroom  
• Multiple type of assessment (quantitative, qualitative, embedded)

Limitations:
• While everyone gained, too much disparity and there was no pre-treatment equivalence  
• Disparity in teaching quality
Final questions and discussion.

• Write questions and answers from the group on any aspect of the design as well as final testing.
• Pre-design research?
• Foundational design?
• Pilot studies?
• Random Control Trial Study?

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