The Hammer-and-Nail Phenomenon: Addressing Students’ Impulsive Disposition in Mathematics Classrooms

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“For a person with a hammer, everything looks like a nail”

(A proverb)
Outline of Presentation

1. Empirical Evidence
2. Pedagogical Significance
3. Theoretical Discussion
4. Classroom Research
5. Open Discussion
1. Empirical Evidence

Evidence #1

\[(5-1)(b+4) = 0\]
\[b^2 + 4b - b - 4 = 0\]
\[b^2 + 3b - 4 = 0\]
\[(b + 4)(b - 1) = 0\]
\[b + 4 = 0 \quad b - 1 = 0\]
\[b = -4 \quad b = 1\]
Evidence #2

A group of 5 musicians plays a piece of music in 10 minutes. Another group of 35 musicians will play the same music. How long will it take this group to play it?

\[
\frac{5}{10} = \frac{x}{35} \\
5x = 350 \\
x = 70 \text{ minutes or } \frac{11}{12} \text{ hr or } 1 \text{ hr } 10 \text{ min}
\]

Only 47% recognized that the answer is 10 minutes. 42% obtained 70 minutes, and 11% found other numbers.

64 Pre-service 4-8 Teachers
1. Empirical Evidence

Evidence #3

Gina is traveling home from her friend’s house. The graph represents a portion of Gina’s journey. What is Gina’s speed at the 20th minute?

![Graph showing distance versus time]

(a) Approximately 3000 meters  
(b) Approximately 50 meters/min  
(c) Approximately 80 meters/min  
(d) Approximately 150 meters/min

Answer:  
A  B  C  D

307 Pre-service EC-4 Teachers
1. Empirical Evidence

Evidence #3

Gina is traveling home from her friend’s house. The graph represents a portion of Gina’s journey. What is Gina’s speed at the 20th minute?

- Time (min)
- Distance from home (meters)

(a) Approximately 3000 meters
(b) Approximately 50 meters/min
(c) Approximately 80 meters/min
(d) Approximately 150 meters/min

Answer: 307 Pre-service EC-4 Teachers
1. Empirical Evidence

Evidence #3

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(a) Approximately 3000 meters
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Answer: A  B  C  D

28%  18%  52%  2%
The Hammer-and-Nail Phenomenon Exists. So What?

- It tells us something important. When it comes to math, students are not thinking.

- It reinforces unhealthy beliefs.
  
  “Doing mathematics means following the rules laid down by the teacher,
knowing mathematics means remembering and applying the correct rule when the teacher asks a question, and mathematical truth is determined when the answer is ratified by the teacher.” (Lampert, 1990, p. 31)

- It can propel us to teach differently.
3. Theoretical Discussion

How Would Researchers Characterize It?

- **Einstellung Effect** (Luchins, 1942)

Task: Obtain target amount of water from 3 jars

<table>
<thead>
<tr>
<th>Problem</th>
<th>Jar A</th>
<th>Jar B</th>
<th>Jar C</th>
<th>Target</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>127</td>
<td>3</td>
<td>100</td>
<td>127 – 21 – 3 – 3</td>
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Adapted from Luchins and Luchins (1970, cited in NRC 2000)
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</tr>
<tr>
<td>3</td>
<td>18</td>
<td>43</td>
<td>10</td>
<td>5</td>
<td>43 – 18 – 10 – 10</td>
</tr>
</tbody>
</table>

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How Would Researchers Characterize It?

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<td>18</td>
<td>43</td>
<td>10</td>
<td>5</td>
<td>43 – 18 – 10 – 10</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>59</td>
<td>4</td>
<td>31</td>
<td>59 – 20 – 4 – 4</td>
</tr>
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How Would Researchers Characterize It?

- **Einstellung Effect** (Luchins, 1942)

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<td>5</td>
<td>43 – 18 – 10 – 10</td>
</tr>
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<td>20</td>
<td>59</td>
<td>4</td>
<td>31</td>
<td>59 – 20 – 4 – 4</td>
</tr>
<tr>
<td>7</td>
<td>23</td>
<td>49</td>
<td>3</td>
<td>20</td>
<td>49 – 23 – 3 – 3</td>
</tr>
</tbody>
</table>

Is there a simpler solution?

23 – 3

Adapted from Luchins and Luchins (1970, cited in NRC 2000)
3. Theoretical Discussion

How Would Researchers Characterize It?

- **Einstellung Effect** (Luchins, 1942)

<table>
<thead>
<tr>
<th>Group</th>
<th>Einstellung Solution</th>
<th>Simpler Solution</th>
<th>No Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (Children)</td>
<td>1%</td>
<td>89%</td>
<td>10%</td>
</tr>
<tr>
<td>Experimental (Children)</td>
<td>72%</td>
<td>24%</td>
<td>4%</td>
</tr>
<tr>
<td>Control (Adults)</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Experimental (Adults)</td>
<td>74%</td>
<td>26%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Adapted from Luchins and Luchins (1970, cited in NRC 2000)
How Would Researchers Characterize It?

- Einstellung Effect (Luchins, 1942)
- Spurious-Correlation (Ben-zeev & Star, 2001)

A two-phase process
- Conceiving an association
- Applying the association to another seemingly similar situation
How Can We Characterize Individuals who Habitually Exhibit the H&N Phenomenon?

• Cognitive Style (Kagan et al., 1964)
  - Matching-familiar-figure test
  - Speed-accuracy continuum

Source: Nietfeld and Bosma (2003)
How Can We Characterize Individuals who Habitually Exhibit the H&N Phenomenon?

• Cognitive Style (Kagan et al., 1964)
  - An *impulsive* person performs tasks rapidly, but usually makes more mistakes.
  - A *reflective* person is slower but more accurate.

• Problem-solving Disposition (Lim, Morera, & Tchoshanov, 2009)
  - *Impulsive disposition* refers to one’s tendency to spontaneously proceed with an action that comes to mind.
  - *Analytic disposition* refers to one’s tendency to analyze a problem situation.
3. Theoretical Discussion

How Can We Characterize Individuals who Habitually Exhibit the H&N Phenomenon?

- **Cognitive Style** *(Kagan et al., 1964)*
  - A personality trait
  - Stable across situation and across time
  - A dichotomy: impulsive versus reflective
  - Characterized by fast-inaccurate responses

- **Problem-solving Disposition** *(Lim, Morera, & Tchoshanov, 2009)*
  - A tendency to act
  - Context-dependent and modifiable
  - A continuum along impulsive-analytic dimension
  - Inferred from errors during problem solving
3. Theoretical Discussion

How Can We Account For It?

- **Human Nature**

  “Our thinking is canalized (or fixed) with respect to the way we have learned to deal with things ... we implicitly anticipate that similar issues have similar causes, and thus similar solutions.”  
  (Reigler, 2001, p. 535)

**Dual Process Theory**

- System 1
  - Associative system
  - Low-level conditioning process
  - Rapid, Automated
  - Implicit, Unconscious
  - Beliefs-based

- System 2
  - Rule-based system
  - Higher-order cognitive processes
  - Slow, Effortful
  - Explicit, Conscious
  - Logic-based
How Can We Account For It?

- Human Nature

- School Effect (i.e. Nurture)

“The tradition has been to regard ‘mathematics’ as a set of rules for writing symbols on paper, and to regard the ‘teaching’ of mathematics as merely a matter of ‘telling’ students what to write and where to write it, together with supervising some considerable amount of drill and practice.”

(David, 1989, p. 159)
How Can We Account For It?

- Human Nature

- School Effect (i.e. Nurture)
  - Compartmentalization of school mathematics
  - Performance-oriented curriculum
  - Clear-and-easy-to-remember instruction
  - Initiate-Respond-Evaluate (IRE) interaction
How Can We Help Our Students Become Less Impulsive?
Motivation

- To get a sense of the ubiquity of the hammer-and-nail phenomenon
- To help students to progress from impulsive disposition to analytic disposition
1. **Two Missing-value Problems**

1. Two identical candles, A and B, lighted at different times were burning at the same constant rate. When candle A had burned 20 mm, candle B had burned 12 mm.

   When candle B had burned 30 mm, **how many** mm would candle A have burned?
1. Two Missing-value Problems

1. Two identical candles, A and B, were burning at the same constant rate. When candle A had burned 20 mm, candle B had burned 12 mm. When candle B had burned 30 mm, how many mm would candle A have burned?

2. Two different candles, P and Q, were burning at different, but constant, rates. When candle P had burned 16 mm, candle Q had burned 10 mm. When candle Q had burned 35 mm, how many mm would candle P have burned?
1. Two Missing-value Problems

Student A’s Solution to Problem 1

\[ x = \text{what A burned when B burns 30mm} \]
\[ A = 20 \quad B = 12 \]
\[ A = \frac{x}{2} \quad B = 30 \]

\[ \frac{20}{x} = \frac{12}{30} \]

\[ 12x = 20 \cdot 30 \]

\[ 12x = 600 \]

\[ x = 50 \text{ mm} \]

Student A’s Solution to Problem 2

\[ x = \text{millimeters candle P burned, when candle O burned 35mm} \]
\[ P = 16 \quad Q = 10 \]
\[ P = \frac{x}{10} \quad Q = 35 \]

\[ \frac{16}{10} = \frac{x}{35} \]

\[ 10x = 16 \cdot 35 \]

\[ 10x = 560 \]

\[ x = 56 \text{ mm} \]
# 1. Two Missing-value Problems

<table>
<thead>
<tr>
<th>Strategy Used for Problem 1</th>
<th>Strategy Used for Problem 2</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportional</td>
<td>Proportional</td>
<td>17</td>
</tr>
<tr>
<td>Additive</td>
<td>Additive</td>
<td>5</td>
</tr>
</tbody>
</table>

28 Pre-service 4-8 Teachers
## 1. Two Missing-value Problems

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<td>5</td>
</tr>
<tr>
<td>Additive</td>
<td>Proportional</td>
<td>4</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>2</td>
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</tbody>
</table>

28 Pre-service 4-8 Teachers
2. The Phenomenon of Over-Learning

Direct-Proportional Item
The ratio of the amount of soda in the can to the amount of soda in the bottle is 4:3. There are 12 fluid ounces of soda in the can, how many fluid ounces of soda are in the bottle?
(a) 8 fluid ounces
(b) 9 fluid ounces
(c) 15 fluid ounces
(d) 16 fluid ounces
(e) None of the above

82 students in 3 sections of MATH 3305
(Rational Numbers & Algebra & Geometry for EC-4)

65 students in 2 sections of MATH 3308
(Rational Numbers & Algebraic Reasoning for 4-8)
2. The Phenomenon of Over-Learning

Direct-Proportional Item
The ratio of the amount of soda in the can to the amount of soda in the bottle is 4:3. There are 12 fluid ounces of soda in the can, how many fluid ounces of soda are in the bottle?

(a) 8 fluid ounces
(b) 9 fluid ounces +14%
(c) 15 fluid ounces
(d) 16 fluid ounces
(e) None of the above

Table:
<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>3%</td>
<td>6%</td>
</tr>
<tr>
<td>(b)</td>
<td>64%</td>
<td>78%</td>
</tr>
<tr>
<td>(c)</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>(d)</td>
<td>27%</td>
<td>11%</td>
</tr>
<tr>
<td>(e)</td>
<td>1%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Inverse-Proportional Item
The ratio of the volume of a small glass to the volume of a large glass is 3:5. If it takes 15 small glasses to fill the container, how many large glasses does it take to fill the container?

(a) 9 glasses -11%
(b) 13 glasses
(c) 17 glasses
(d) 25 glasses +16%
(e) None of the above

Table:
<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>53%</td>
<td>42%</td>
</tr>
<tr>
<td>(b)</td>
<td>9%</td>
<td>13%</td>
</tr>
<tr>
<td>(c)</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>(d)</td>
<td>24%</td>
<td>40%</td>
</tr>
<tr>
<td>(e)</td>
<td>10%</td>
<td>2%</td>
</tr>
</tbody>
</table>
### 2. The Phenomenon of Over-Learning

<table>
<thead>
<tr>
<th>Pair #1</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>44%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>+18%</td>
<td>68%</td>
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</table>

<table>
<thead>
<tr>
<th>Pair #2</th>
<th></th>
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<tr>
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<td></td>
<td>3%</td>
<td>27%</td>
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<td></td>
<td>64%</td>
<td>11%</td>
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<tr>
<td></td>
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<td>2%</td>
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<tr>
<td></td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>+14%</td>
<td>68%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pair #3</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td></td>
<td>26%</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>59%</td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td>13%</td>
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### Classroom Research

- **Pretest**
  - Pair #1: 49%
  - Pair #2: 53%
  - Pair #3: 49%
- **Posttest**
  - Pair #1: 64%
  - Pair #2: 42%
  - Pair #3: 56%

#### Percentage Change

- **Pair #1**
  - Pretest: +18%
  - Posttest: +14%
- **Pair #2**
  - Pretest: +11%
  - Posttest: +16%
- **Pair #3**
  - Pretest: -13%
  - Posttest: +7%

- **Overall**
  - Pretest: -13%
  - Posttest: +16%
3. Reducing Overgeneralization of Proportionality

Research Questions

1. Can students’ tendency to overgeneralize proportionality be reduced in one semester?

2. Will the use of non-proportional MVPs help students minimize their improper use of proportional strategies?
3. Reducing Overgeneralization of Proportionality

Research Design

- Two sections of MATH 3308
- Two-part study

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 3</th>
<th>Week 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDDD Class</td>
<td>4 Prop MVPs</td>
<td>Intervention</td>
</tr>
<tr>
<td>Pre-test</td>
<td>Post-test</td>
<td></td>
</tr>
<tr>
<td>DADI Class</td>
<td>2 Prop &amp; 2 Non-P MVPs</td>
<td>Intervention</td>
</tr>
<tr>
<td>Pre-test</td>
<td>Post-test</td>
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3. Reducing Overgeneralization of Proportionality

**Research Design**

- Two sections of MATH 3308
- Two-part study
- Three Tests
  - Post-test is structurally equivalent to pre-test
  - End-test is identical to pre-test
3. Reducing Overgeneralization of Proportionality

Research Design

- Two sections of MATH 3308
- Two-part study
- Three Tests
  - Post-test is structurally equivalent to pre-test
  - End-test is identical to pre-test
  - 13 Multiple-choice Items
    - 2 Proportional MVPs
      - 2 Ratio Comparison Problems
    - 6 Non-proportional MVPs
    - 3 Non-ratio Comparison Problems
3. Reducing Overgeneralization of Proportionality

Research Design

- Two sections of MATH 3308
- Two-part study
- Three Tests
- Semester-long Intervention
  - Used problem-based learning strategies
  - Included superficially-similar-structurally-different problems
Superficially-similar-structurally-different to a Ratio-comparison Problem

Sharon and Terri were comparing the size of their palms. Who do you think has a larger palm?

\[ N = 22 \quad N = 62 \]

41% 21% Compared ratios
14% 10% Compared differences
0% 10% Compared perimeters/sums
45% 46% Compare products/areas
0% 13% Others

Sharon’s hand is larger because the ratio of the length and width is closer to 1 than Terri’s hand ratio.

\[ \frac{84\, \text{mm}}{90\, \text{mm}} = 0.9333, \quad \frac{70\, \text{mm}}{150\, \text{mm}} = 0.4667 \]
3. Reducing Overgeneralization of Proportionality

Research Design

- Two sections of MATH 3308
- Two-part study
- Three Tests
- Semester-long Intervention
  - Used problem-based learning strategies
  - Included superficially-similar-structurally-different problems
  - Emphasized quantitative reasoning (Thompson, 1993)
Focus on Quantities

1. Two identical candles, A and B, lighted at different times were burning at the same constant rate. When candle A had burned 20 mm, candle B had burned 12 mm.

When candle B had burned 30 mm, how many mm would candle A have burned?

List the quantities.

20, 12, and 30
20mm, 12mm, and 30mm
Focus on Quantities and Relationships

1. Two identical candles, A and B, were burning at the same constant rate. When candle A had burned 20 mm, candle B had burned 12 mm. When candle B had burned 30 mm, how many mm would candle A have burned?

\[ 20 - 12 = x - 30 \]

**Diagram:**
- 20 mm
- 12 mm
- 20 - 12 = x - 30
- Difference is invariant
2. Two different candles, P and Q, lighted at the same time were burning at different, but constant, rates. When candle P had burned 16 mm, candle Q had burned 10 mm. When candle Q had burned 35 mm, how many mm, how many mm would candle P have burned?

\[
\frac{16}{10} = \frac{x}{35}
\]

Ratio is invariant
3. Reducing Overgeneralization of Proportionality

Research Design

- Two sections of MATH 3308
- Two-part study
- Three Tests
- Semester-long Intervention
  - Used problem-based learning strategies
  - Included superficially-similar-structurally-different problems
  - Emphasized quantitative reasoning (Thompson, 1993)
  - Focused on meaning
2. Two different candles, P and Q, lighted at the same time were burning at different, but constant, rates. When candle P had burned 16 mm, candle Q had burned 10 mm. When candle Q had burned 35 mm, how many mm would candle P have burned?

What does 3.5 represent?

Why is $x/16$ equal to 3.5?
3. Reducing Overgeneralization of Proportionality

Research Design

- Two sections of MATH 3308
- Two-part study
- Three Tests
- Semester-long Intervention

Research Results

- 2 Proportional MVPs
  2 Ratio CPs
- 6 Non-proportional MVPs
- 3 Non-ratio CPs
4. Classroom Research

Research Results

DDDD class (N = 35)  
DADI class (N = 31)
4. Classroom Research

Research Results

DDDD class (N = 35)  
DADI class (N = 31)
Research Results

DDDD class (N = 35)

DADI class (N = 31)

RQ1 Can pre-service teachers’ tendency to overgeneralize proportionality be reduced in one semester?
F1. Students’ tendency to overuse proportions and ratios was reduced in one semester.
4. Classroom Research

Research Results

**DDDD class (N = 35)**

**DADI class (N = 31)**

RQ2 Will the use of nonproportional MVPs help pre-service teachers’ minimize their improper use of proportional strategies?
Research Results

F2. Exposure to proportional MVPs increased students’ overuse of proportionality.
F2. Exposure to proportional MVPs increased students’ overuse of proportionality.
F3. Inclusion of non-proportional MVPs seemed to minimize students’ overuse of proportionality.
3. Reducing Overgeneralization of Proportionality

**Students’ Comments**

- “I learned to analyze the problem *instead of rushing into a procedure*, I used to do that.”
- “This class helped me ... by *thinking deeper about that problem* instead of just looking at the numbers and wanting to do something with them.”
- “In this class, the concepts remain the same, yet the problems themselves are always quite different. I can no longer rely on ‘similar problems’ in order to figure out my homework or pass [the] exams.”
- “This class is very demanding because I have to dedicate more time to *learn how to get rid of those ‘bad habits’* that I have learned in previous classes.”
 Calls for Manuscripts

In addition to active calls for manuscripts on particular topics listed below, the Editorial Panel of MTMS is interested in publishing articles on a full range of topics in middle school mathematics education. To learn more about writing for the journals, visit www.nctm.org/publications, then click on “Write for NCTM.”

FOCUS ISSUE CALL 2012
Deadline: January 3, 2011

Fostering Mathematical Reasoning
Mathematical reasoning and sense-making are critical aspects of doing math. Manuscripts submitted for the Focus Issue should address the process of sense-making or effective tools for students to reason in mathematics. Habits of mind, proof, representations, curriculum, deductive and inductive reasoning, and technology can each be considered in this context, as well as strategies used by teachers or challenges they face when they decide to foster mathematical reasoning in the classroom.

OPEN CALLS
No submission deadline

Promoting Discourse
The Editorial Panel is interested in manuscripts that demonstrate effective discourse in the mathematics classroom. Discourse allows students to articulate their own perspectives and ideas and engages students in constructing their mathematical understandings.

Addressing Equity
Creating and sustaining a culture of equity in the teaching and learning of mathematics is a challenge for today’s teachers. The Editorial Panel is interested in manuscripts that address issues of equity in the classroom.
Thank You