Update on Research

(Very Preliminary Report of Findings)

David Carraher

Carol Smith

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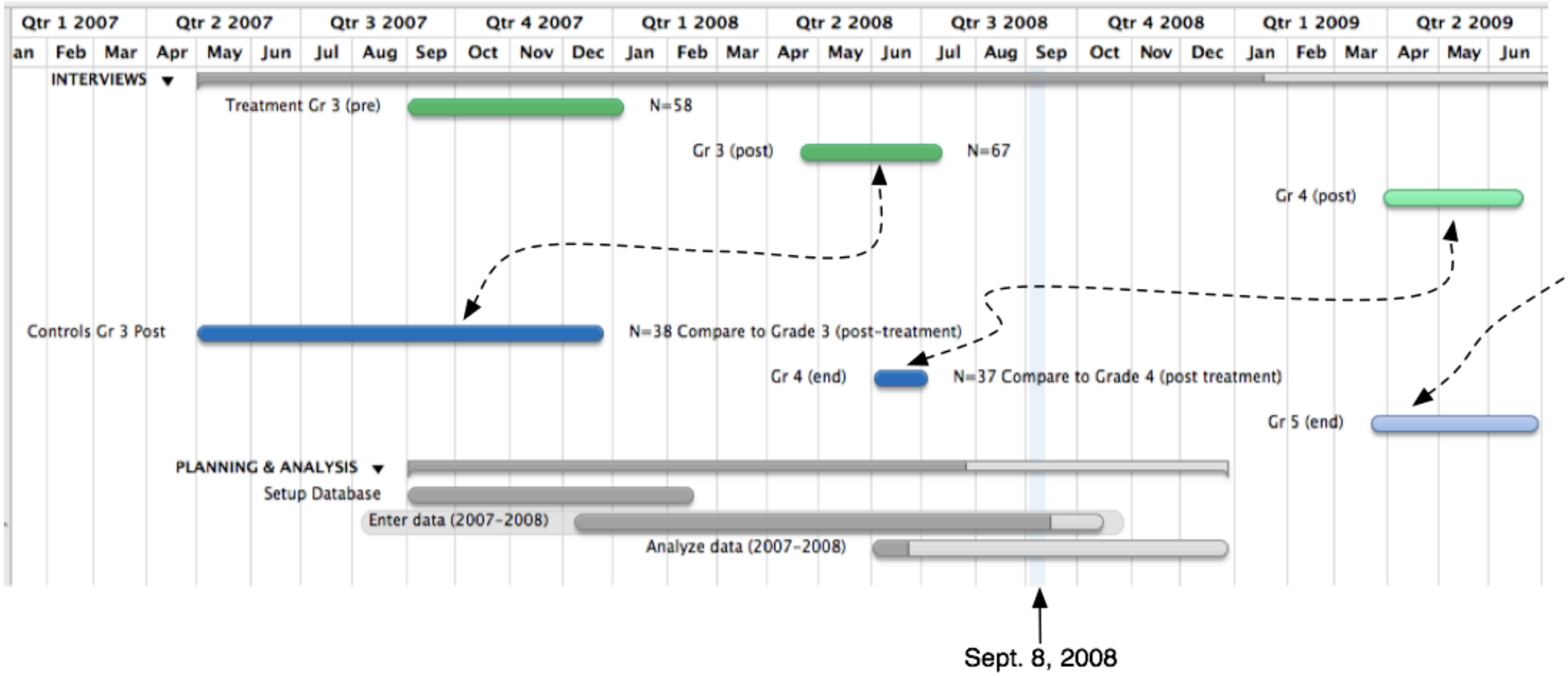
Twin Goals of the Research

- **Reasoning**: Provide a rich description of the evolution of student concepts of material, weight, volume, and density across grades 3 to 5
  - What is the nature of students' reasoning? What variety of forms does it take on?
  - How do changing understandings support each other?
  - What mathematical structures and representations play critical roles in their understanding of the science?

- **Impact**: To assess the impact of Inquiry units in fostering deeper macroscopic understanding of matter (and related concepts) during this time

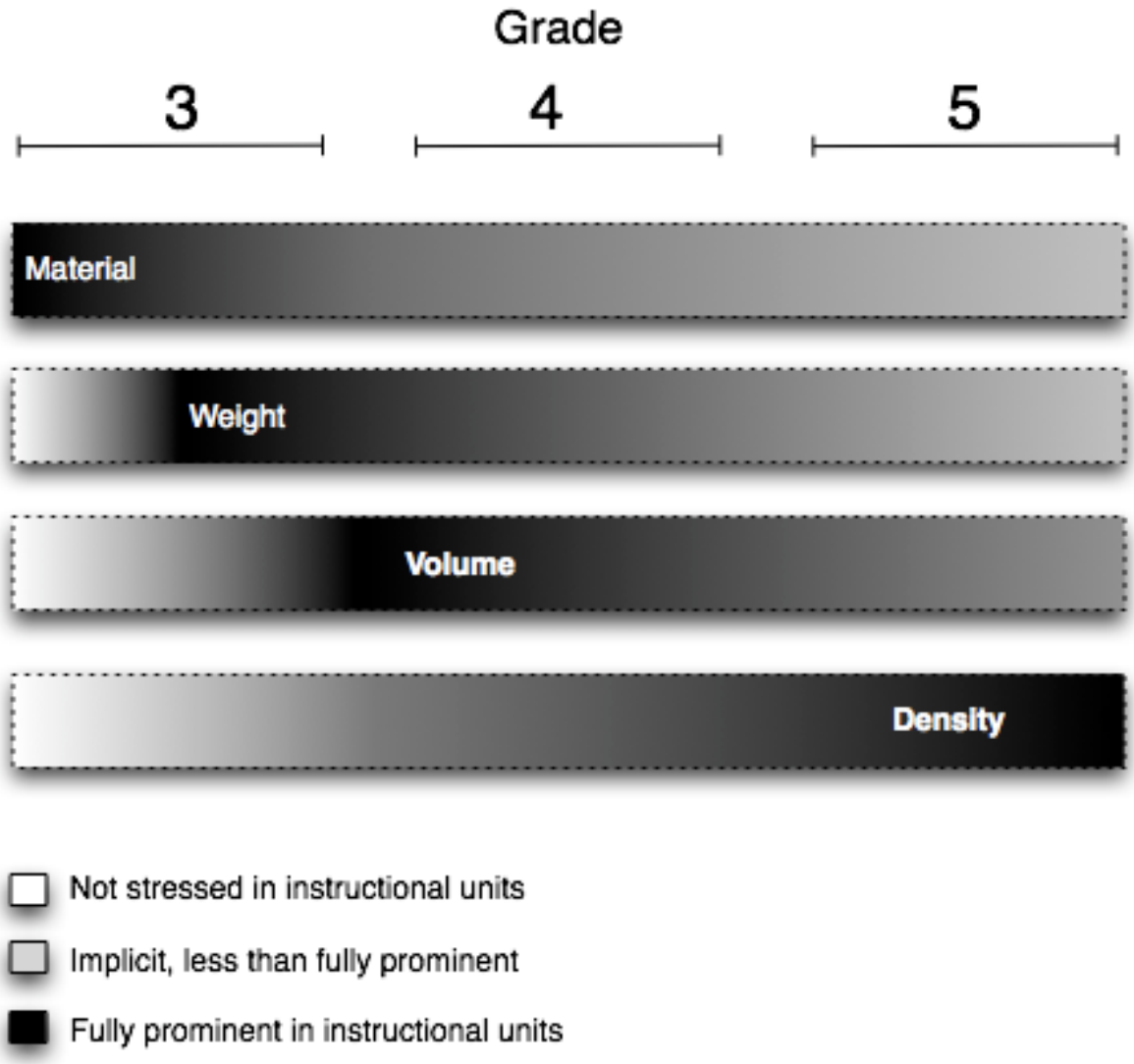
Research Timeline



Curricular Foci: I

- **Grade 3:**
  - Solid materials of different kinds (e.g., density cubes)
  - Weight: felt weight, weight measurement, weight line representations
  - Volume (brief introduction to idea of taking up space, conservation of volume across shape change, and measurement of volume through building replicas)
- **Grade 4:**
  - Different kinds of Earth materials that may take solid, granular, or liquid forms
  - Weight differences of these materials and weight line representations
  - Volume: more extensive discussion and development, including understanding of phenomena of displacement, distinguishing volume of stuff from volume of container, multiple approaches to measurement of volume, etc.
  - Beginning to consider relations among weight and volume
  - Exploring effects of transformations (e.g., grinding) and conservation of weight across those transformations
- **Grade 5: ???**
  - All Matter has Weight and Volume
  - Gases as forms of matter
  - Density of Materials (and concentrations): more formal development

Curricular Foci: II



Some Premises: Material & Matter

- Material and Weight as Lever Concepts
  - Both accessible to even preschoolers
  - Both potentially densely connected to other concepts in network
  - Each initially has a more perceptually based core *(i.e, materials as cluster of perceptual properties; weight as felt weight)*
  - Each undergoes significant restructuring in interaction with each other, other concepts in network, and mathematical ideas

- Matter as Emergent Concept
  - Initially more implicit than explicit concept
  - Highlights commonalities among solids, liquids, and granular materials
  - Also undergoes restructuring: from having perceptual core (*see, feel, touch*) to one based on measured quantities (*weight, volume*) which in turn supports ontological change (*reconceptualizing gases as matter*)

Unmeasured Physical Quantities

Judgments about **unmeasured (and, often, unlabeled) physical quantities** key to many research and instructional tasks.

E.g. Comparisons of…

a. Ribbons (length)
b. Cards (area)
c. Blocks, cylinders (volume, weight)
d. Large and small pieces of clay (weight, volume…)
e. Water levels

Unmeasured Quantities

Research and instructional tasks often employ comparison of **unmeasured quantities** to focus on:

a. Identification of property: e.g. volume
b. Differences & ratios
c. Extension of the property: divisibility of clay
d. Granularity of the property: line lengths
e. Preservation under transformations: reshaping, melting…

Quantities & Continua

Measurable Quantities Need to Be Conceptualized as Locations (and Intervals) on Continua

a. Orderable
b. Subject to operations of addition, subtraction, multiplication and division
c. Measure lines are similar to but also different from Number Lines

Material:
Key Pretest Findings (Grade 3)

- T9: Although most understood that something *could be* the same material when transformed by cutting into pieces or melting, many fewer *consistently* judged this was the case and understood burning and magnetic attraction as specific properties of materials
  - Often uncoordinated focus on perceptual properties (hard/soft, color, smell, taste), transformations (rubbing, melting) and origins (where it came from)

- T3: Limited use of differences in material in explaining weight differences of two objects (covered in contact paper): (a) same size, different weight; or (b) smaller object is much heavier
  - Some no explanation, or explanations in terms of whether empty/hollow, what objects/things filled with, or amount of stuff/things inside.

- T3: Limited (generic) vocabulary for discussing materials (e.g., in few cases where mentioned materials, almost always used general terms like rock, wood, metal, plastic rather than granite, pine, iron, PVC)

Material:
Pre to Posttest Change (Grade 3)

- More *consistently* judged still same material (wood, iron, butter) and same kind of stuff across grinding/melting transformations (6 items)
- More *consistently* judged sawdust would burn and iron filings would be attracted to magnet (2 items)
- More *consistently* judged both same material and properties (8 items)

T9: Pattern of Judgment	**Pretest**	**Posttest**
Still same material & stuff (6 correct)	48%	77%
Still same properties (2 correct)	43%	69%
Still same material & properties (8 correct)	25%	59%

Material:
Pre to Posttest Change (Grade 3)

- Dramatic increase in number who consider kind of material as relevant to explaining weight differences of objects in Problems 2-3 (Task 3, Part 1)

Problem Type	**T3: Type of Explanation**	**Pretest**	**Posttest**
C < B **(P1)** 	% Who Focus on Size as relevant *(e.g., B is heavier because it's bigger)*	79%	68%
A > C **(P2)**  A > D **(P3)** 	% Who Focus on Kind of Material or Heaviness of Material in Problem 2-3 *(e.g., they are made of different kinds of materials, A might be metal, D wood)*	27%	73%
A = B **(P4)** 	% Who Differentiate Heavy from Heavy kind of Material *(e.g., A may be a heavier kind of material, B a lighter kind)*	7%	23%

Material:

Change in Sophistication of Material Kind Vocabulary (Task 3)

Pre:	**Post:**
Metal	Metal, plastic
Metal, plastic, rock	Pine, Oak, Acrylic, Steel Copper
Stone	Copper Aluminum, Steel, Nylon
Metal, plastic, wood	Metal, plastic, rock
Metal	Wood, plastic
Metal, gold, silver	Copper, pine, oak
Metal	Plastic, copper
Metal	Metal, wood, concrete, plastic
Stone metal wood	Copper, aluminum
Metal	Copper, steel
Metal	Steel
Metal, wood	Plastic, metal, steel, copper
Wood	Rock, cement, metal
Metal, wood	Plastic, iron
Metal	Plastic
Metal, glass	Metal, copper
Plastic	Metal, PVC, plastic, wood
Metal, wood	Copper, iron, steel
Metal	Copper, aluminum
Metal, cardboard, iron	Copper, plastic, metal
Metal	Plastic, metal, copper, steel
Metal, wood	Bronze, steel
Metal, plastic	Metal, plastic
	Copper, plastic, wood
	Iron, brass
	Steel, brass, copper, wood, aluminum
	Copper, aluminum foil, wood, steel
	Brass, aluminum
	Copper, steel, brass, aluminum, wood, nylon and poplar
	Steel, plastic, and aluminum
	Wood
	Copper, PVC, Pine, Steel
	Brass, copper, steel, pine, aluminum, and acrylic
	Wood, metal

Concept of Weight: Key Pretest Findings (Grade 3)

- Although majority think the weight and amount of material do not change across shape transformations (e.g., ball vs. pancake, snake vs. block shape), many fewer are *consistently* correct in making these judgments across items in both tasks and also making correct predictions that the items will still balance on the scale
  - *Question: Why so much inconsistency in judgments?*

- About half could not use a scale and gram weights to determine the weight of an object (even with our scaffolding) and were unsystematic in their approach to using a balance scale to measure
  - *Question: Why so much difficulty finding the weight of an object?*

- Finally, children almost universally judged that a small piece of clay weighed nothing at all!
  - *Question: Why might they think that?*

Weight:
Pre to Posttest Change (Grade 3)

- Increased consistency of judgments that shape change does not affect amount of clay/plastic, weight of the objects (e.g., ball, pancake), and how behave on balance scale! (T5 Clay Deformation, T6 Block Rearrangement)

Judgment Pattern	**Pretest**	**Posttest**
% Judge that Pancake and ball have same Amount of Clay, Weigh same and both will Balance (3 items)	57%	80%
% Judge that Snake and Block have same Amount of Plastic, Weight, and both will Balance (3 items)	57%	77%
% Consistently Correct on these Questions for Both Tasks (6 items)	45%	71%

Weight:
Pre to Posttest Change (Grade 3)

- Improved ability to use balance and gram weights to determine weight of object, and to do so systematically!

Task 6B Weight Measurement	**Pretest**	**Posttest**
% able to use balance and set of gram weight to find weight of object (8-9gm)	54%	89%
% very systematic in sequence of moves (corrects in right direction, remembers previous tries, recognizes equivalences)	41%	70%

Weight:
Pre to Posttest Change (Grade 3)

- Improved understanding that small things have weight and take up space!

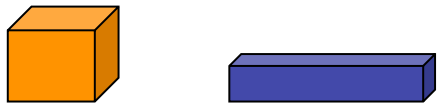
Task 1: Granularity of Clay	**Pretest**	**Posttest**
% Judge Speck has Wt	11%	70%
% Judge Speck takes up Space	45%	79%
% Judge can be piece too tiny to see	71%	75%
% Judge invisible piece takes up Space	34%	54%
% Judge invisible piece has weight	9%	52%
% Judge always there with repeated division	54%	70%

Volume:
Key Pretest Findings (Grade 3)

- Before Grade 3, children generally judged the size of objects by attending to properties and relations not consistent with volume conventions
- The majority thought that flattening a ball into a pancake or rearranging blocks into different shapes changed their volume
  - Most emphasized what we would consider to be length or area, judging that the flat pancake and long snake took up more space

- Almost all thought took weight, not volume, into account when predicting water displacement.

- Almost none measured the size of two objects rectangular objects (I.e., which fills up the most space) by building a replica with cubes, or using a tape measure and calculation)
  - Many simply measured the lengths of one the sides
  - Others the perimeter of each object
  - Some the area of the top face
  - A few the surface area



Space Filled by Objects ("Volume") Pre Posttest Change (Grade 3)

- Children made some improvement in understanding volume, although the level of insight varied considerably on different tasks

Task	**Pretest**	**Posttest**
Snake and Block arrangements thought to take up the same space (T6 Block Rearrangement)	30%	63%
Clay as Pancake and Ball take up same amount of space (T5 Clay)	21%	41%
"Volume of Two Blocks measured correctly (T2)	5%	23%

  - *Question: Why the difference in success rates for different tasks?*

- Most still thought water displacement depended on the weight of objects (something not yet addressed in the curriculum)

Concept of Matter: Key Pretest Findings (Mason, Grade 3)

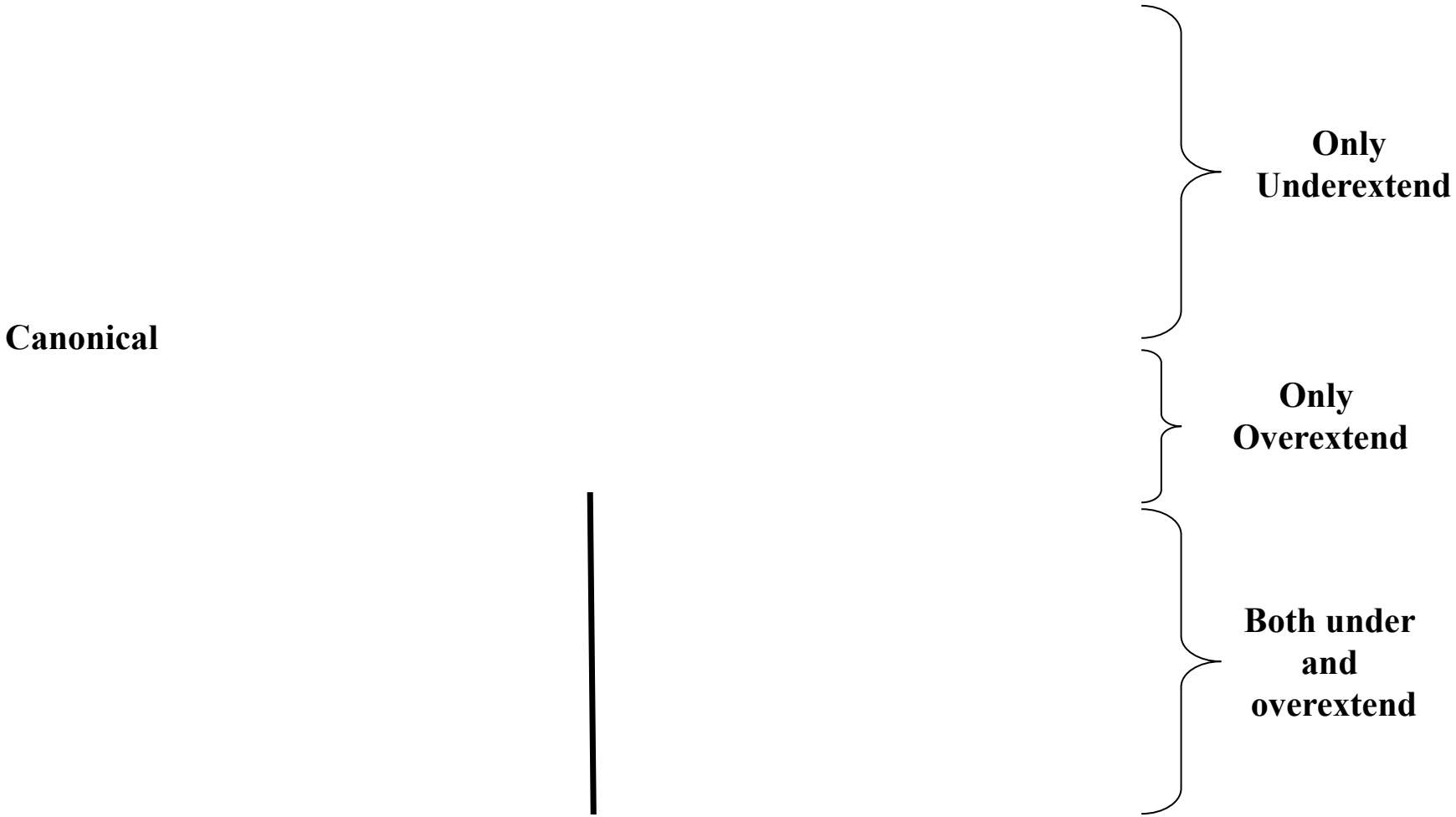
• Many do not have a coherent concept of matter (mapped to the word "matter") and make both *under and over-extension errors* in judgments

• Those have more systematic patterns, typically only underextend, excluding gases and often even water

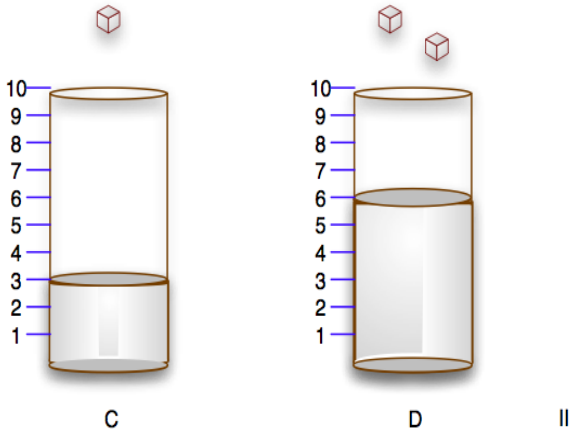
Concept of Matter:
Pre to Posttest Change (Mason, Grade 3)

Many more had systematic patterns by posttest, although except in one case, not yet "canonical" patterns

Concept of Matter:
Pretest (Forestdale, Grade 3)



Concept of Matter:
Posttest (Forestdale, Grade 3)



Task 10:
Which is sweeter?

Comparison Pairs	% Correct Before	% Correct After
2/4 > 2/6	42	56*
1/3 = 2/6	12	14*
3/8 < 2/4	16	44*
2/3 > 1/2	75**	70**

Overview of Tasks: Interview

(sample questions)

- **Understanding of materials & their transformations (T9)**
  - If you grind up wood is it still wood? Would it still burn? Why?
  - If you melt butter, is it still butter? Is it still the same kind of stuff?

- **Matter, not matter sorting (T7)**
  - Sort the following (wood, sand, milk, air, heat, shadow….) into 3 piles: matter, not matter, not sure. How did you know? Any common properties of matter?

- **Conservation of amount of matter, weight, volume across shape change (T5A Clay Deformation & T6A Block Rearrangement)**
  - T5A: Do the ball and pancake have the same amount of clay, weigh the same? Take up the same of space (have same volume)?
  - T6A: Does each construction take up the same amount of space? Weigh the same? Have the same amount of plastic?

- **Divisibility and granularity of clay (T1)**
  - Does this (tiny speck) of clay have any weight? Take up any space?
  - Could there be a piece so small you can't see it? Would it have any weight?
  - If we repeatedly divided a piece of clay in half and in half again, would we get to a point where there was nothing left, or would something always be there?

Overview of Tasks: Interview (cont'd)

- **Weight measurement (T6B)**
  - Can you use balance scale and gram weights to figure out how much this block weighs?

- **Length, area, and volume measurements (T2)**
  - Is one of these two lines longer? How long is each line?
  - Does one of these two cards cover more space on table? How much space?
  - Does one of these blocks take up more space? How much does each take up?

- **Differentiating and inter-relating weight, volume, and density (T3)**
  - How can a smaller of two objects be heavier?
  - Which is made of a heavier kind of material: a brass shaving or a large piece of aluminum?
  - Can you tell what material these covered cylinders are made of?

- **Granularity of number and length (T8)**
  - Are there any numbers between 4 and 5? How many? Can you always find a number between any given numbers?
  - Are there any lengths between the length of this line (A) and this (B)? How many?

- **Proportional reasoning and sweetness (T10)**
  - Is 3 sugar cubes in 8 units of water sweeter than 2 sugar cubes in 4 units of water?