Assessing Students' Evolving Understandings of Matter

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The Inquiry Project

A comparative longitudinal investigation of students' thinking about matter from ages 8-11 (Grades 3-5)

- Treatment: Inquiry Curriculum
- Control: standard approach used in schools

Evolving concepts of material, weight & mass, volume, density and state of matter

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Two Strands

Builds on a learning progression about matter proposed by Smith, Wiser, Anderson, and Krajcik, (2006).

Investigates the development of ***quantitative reasoning*** regarding key concepts—reasoning abou physical quantities in ways that highlight certain properties, structures and relations.

- *What should we be doing early on if we want our children to reach adolescence already highly literate, mathematically sophisticated, skilled in scientific investigation and debate ?...*

- Much of modern science is built around events and processes at an atomic-molecular scale beneath the threshold of direct apprehension

- What should we be doing early on to prepare the foundations for such later science learning?

Potential Pitfalls

‘Developmental Readiness’

‘Accelerated instruction’

Caveat

Foundations Likely to Be Very Different from Desired End States

Two Overarching Themes

A shift from *perception-centered thinking* to *model-mediated thinking* regarding scientific concepts

The emergence of *quantitative reasoning* in a domai (e.g. viewing extensive quantities as dense continua having a metric and being subject to certain operations and properties; understanding continuous covariation among two or more quantities…)

Concepts

Invariants—objects, properties, and relations—relevant to…

Situations and conditions and expressed through…

Conventional and personal *systems of symbolic representation*.

What are the relations between concepts and models?

Examples from Inquiry Research

Existence and properties of tiny things

Granularity of length, weight, number

Learning about Density

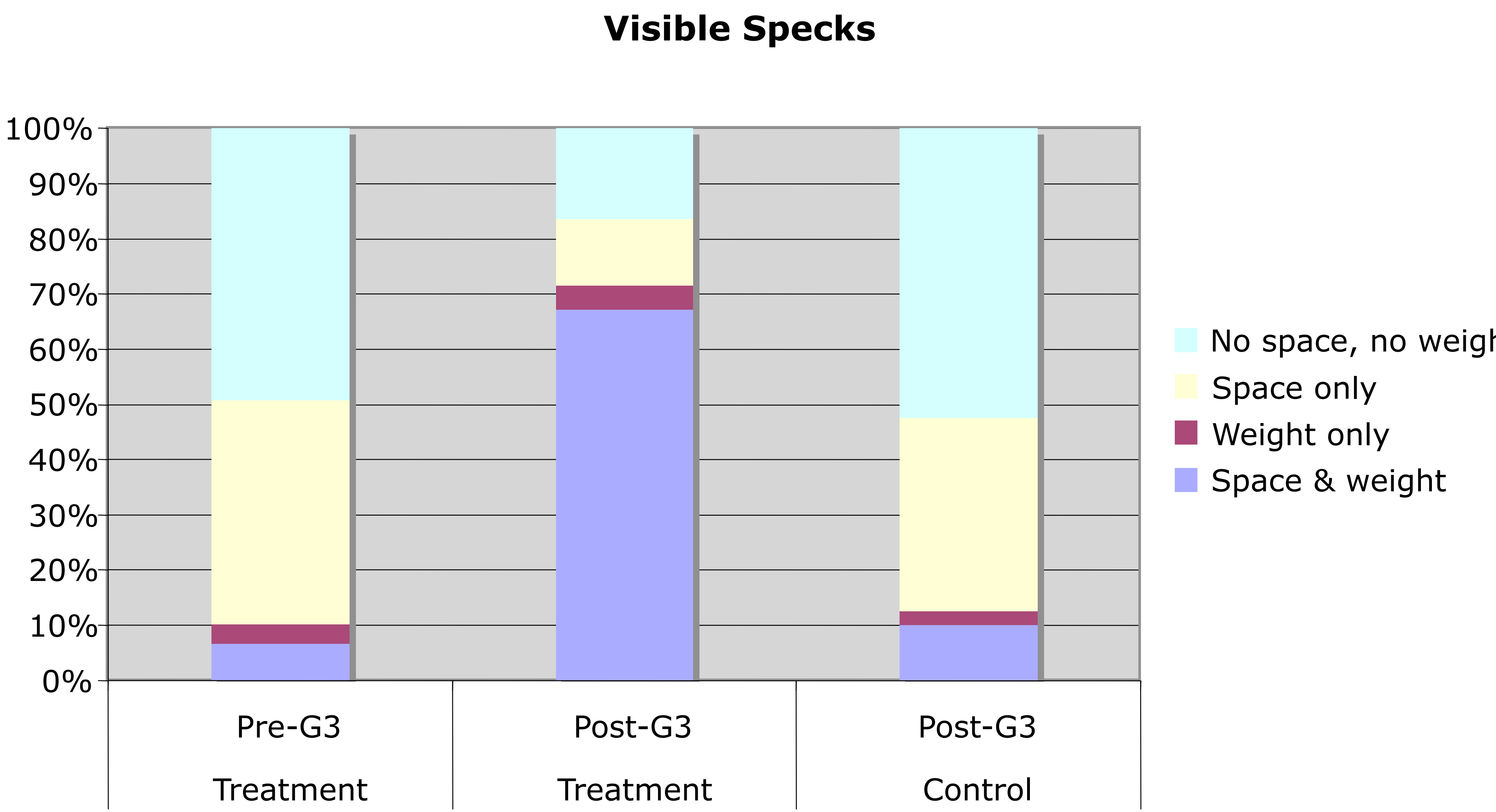
The Concept of Volume

1-Properties of tiny things

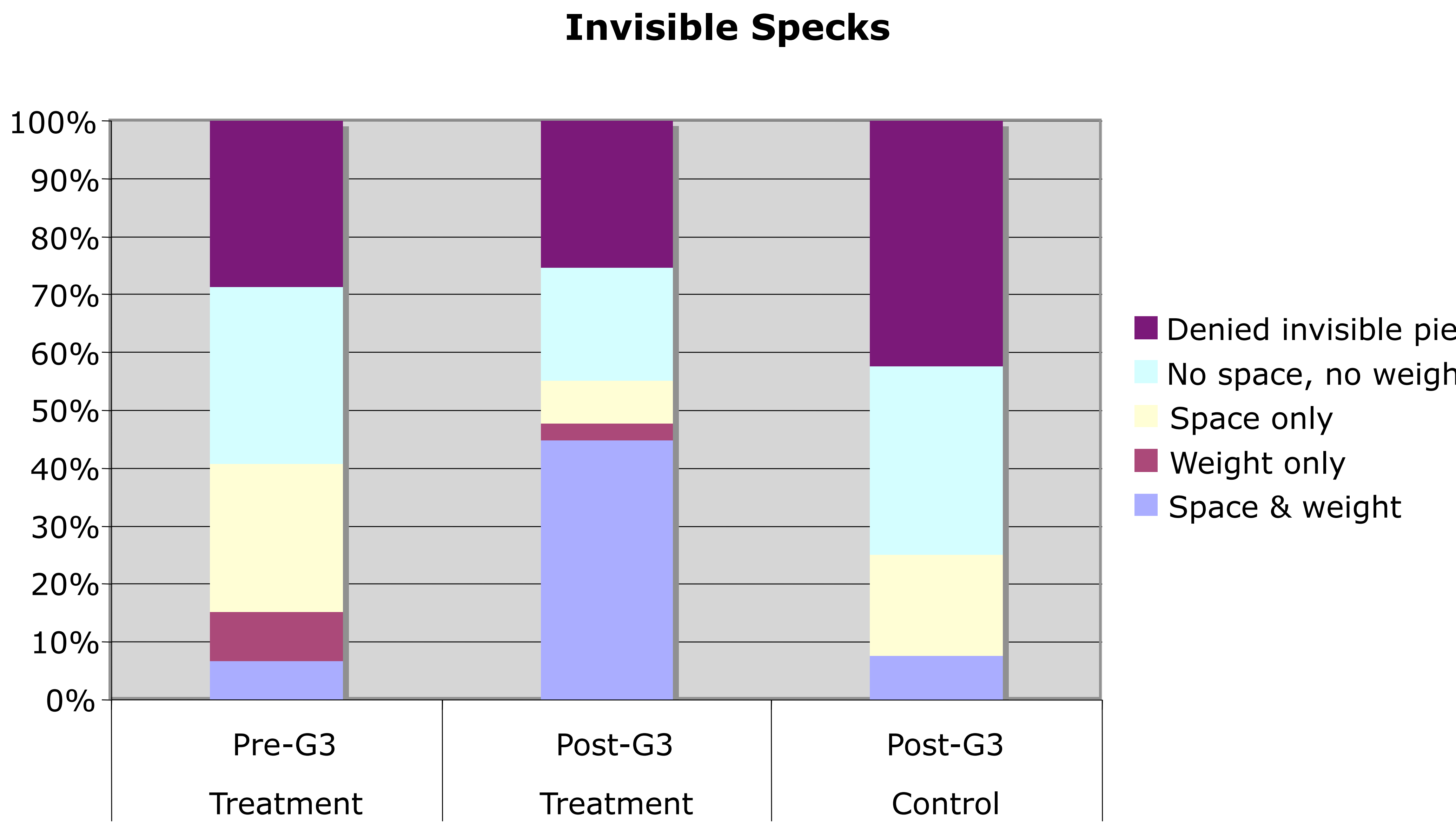
Does a tiny speck of clay have any weight? Take up any space?

Could there exist a speck of clay so small as to be invisible? Would it weigh anything? Would it take up any space?

If you repeatedly take half of a bit of clay, (then half of that...) would you ever end up with nothing at all?



Visible Specks
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pre-G3 Treatment
Post-G3 Treatment
Post-G3 Control
No space, no weigh
Space only
Weight only
Space & weight



Invisible Specks
100%
90%
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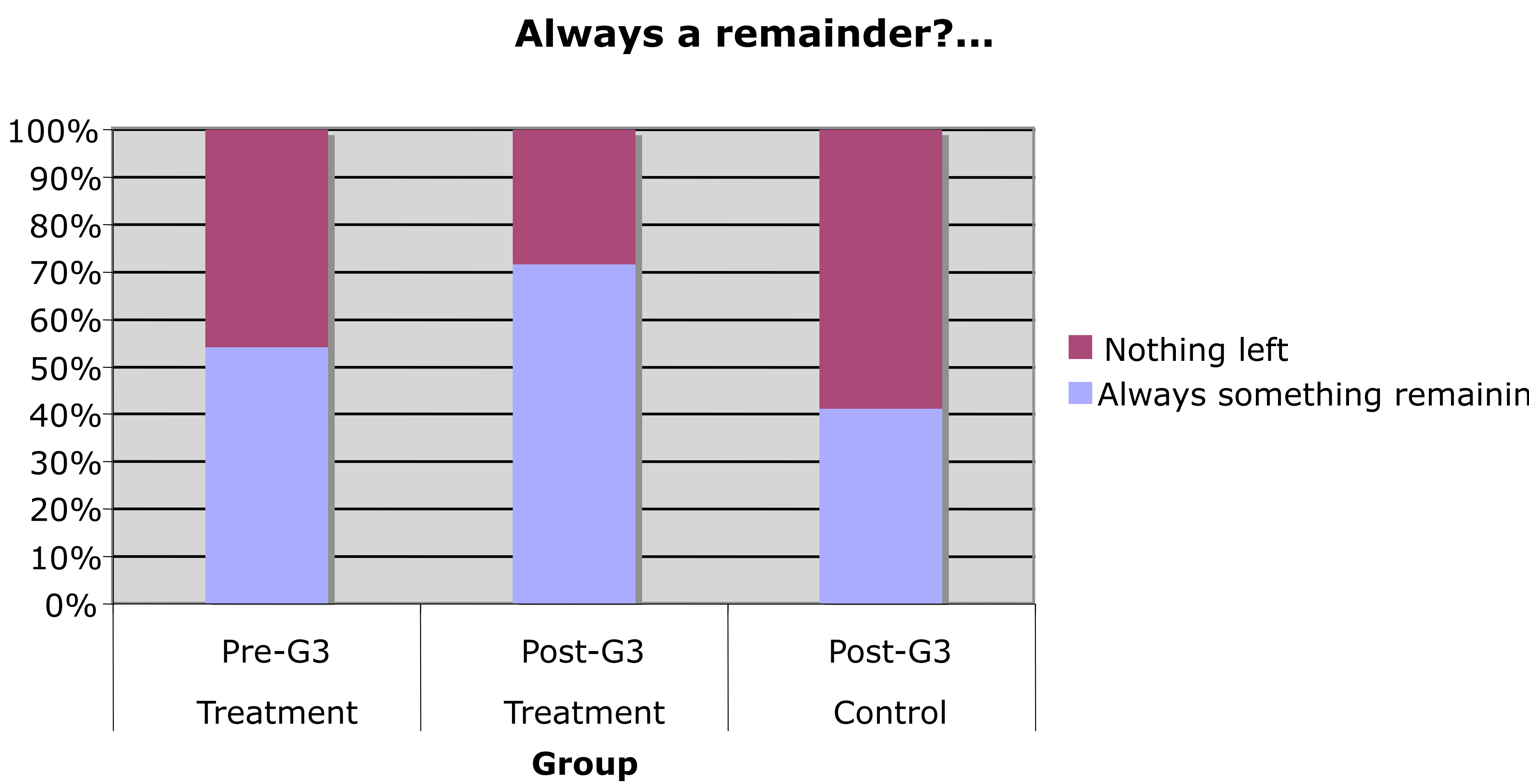
No space, no weigh
Space only
Weight only
Space & weight


Always a remainder?...
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pre-G3 Treatment
Post-G3 Treatment
Post-G3 Control
Group
Nothing left
Always something remainin

2-I Physical Quantities & Numbers as Dimensions

Some physical quantities can be thought of as a *dimension* along which the amount or intensity of an attribute (weight, volume, brightness, distance…) can be spatially ordered.

The dimension has a metric if there is an agreed upon way to assign values to locations and distances (intervals) on the continuum.

Distances correspond to differences in the attribute

Ratios correspond to relative magnitudes of distances

There
Between 4 and 5?

- Many (>80%) third grade students spontaneously assert there are no numbers between 4 and 5.
- The majority acknowledge that 4 and one-half lies between 4 and 5 (when suggested)
- Most believe there are only a few numbers (e.g 4¼, 4½, 4¾) in that interval.

Dividing by 2

- **What is 1/2 of 2?**
- **What is 1/2 of 1?**
- **Can we keep going? Would we ever get to 0?**

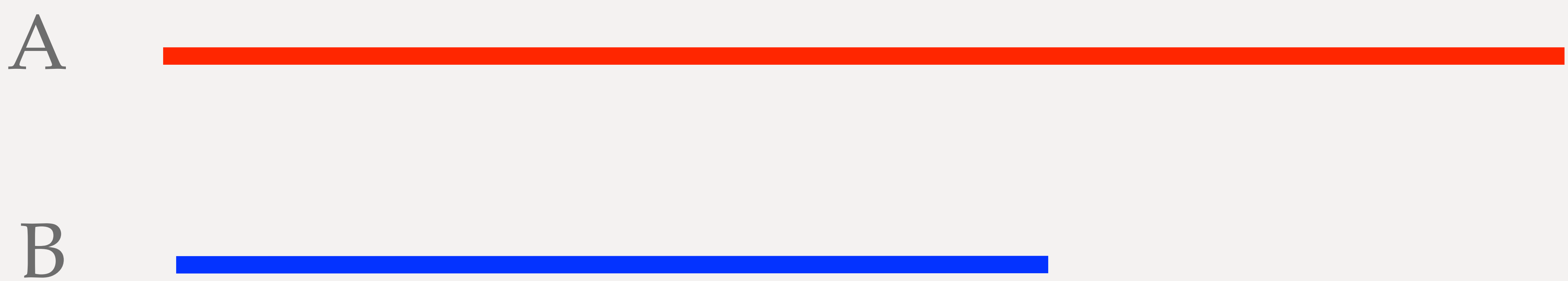
Results:

- Many students not know that one-half of 1 is ½
- Many think that halving terminates (leaving nothing at all).
- **What are the links between division by 2 and repeatedly halving amounts of matter?**

Granularity of length

“How many different lengths could there be between the lengths of lines A and B?”

The vast majority of third grade students believe that very few lengths exist that are shorter than A and longer than B.



Granularity of Weight

How many weights could exist between those of the smaller and larger ball of clay

Almost all third graders believe that very few weights exist between that of the blue ball and the red ball of clay (even though one is 3 times as heavy as the other)

They seem to believe that for objects to have

Infinitesimal changes in co-variation

"If you throw a rock into a lake, will the water level rise?"

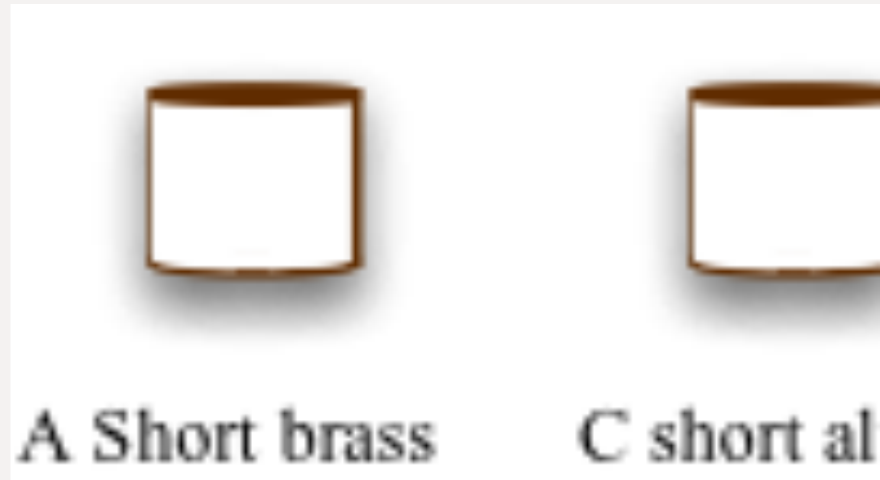
Models require the acknowledgemen of 'infinitesimal' differences in values.

A perceptible change in x can lead to an imperceptible change in y

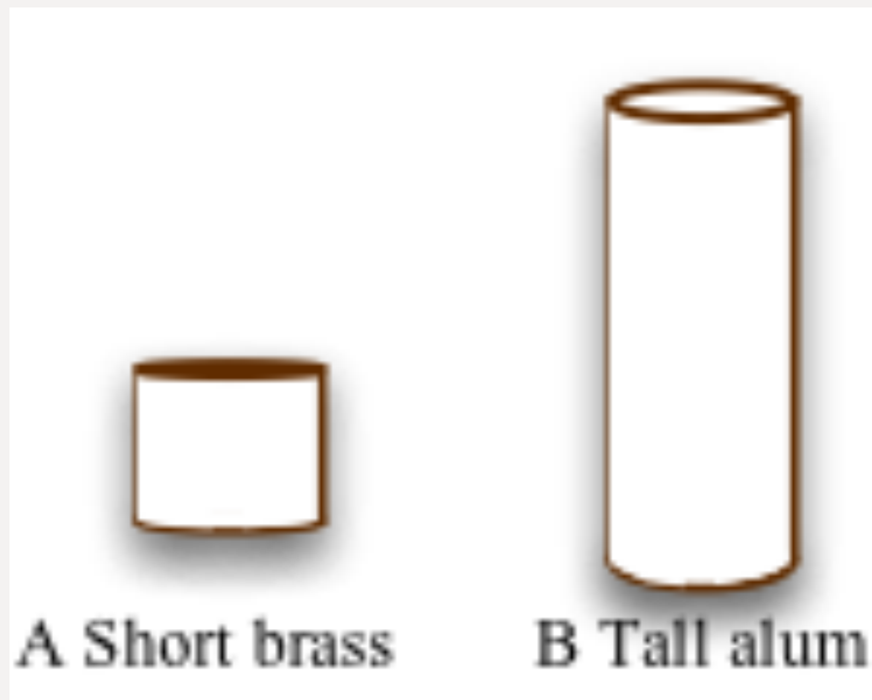
1Weight, Size, & Heaviness of Material

rger is not Always Heavier

do you think **A is heavier** than C & D?

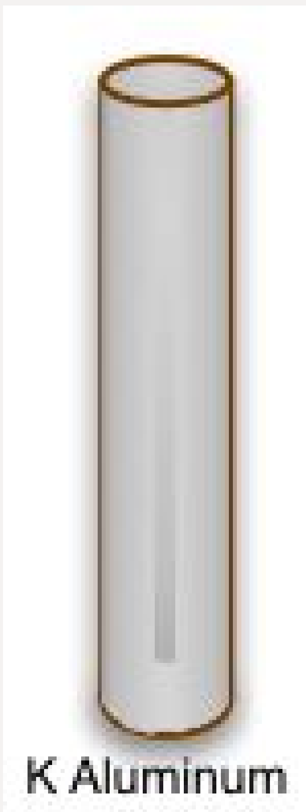


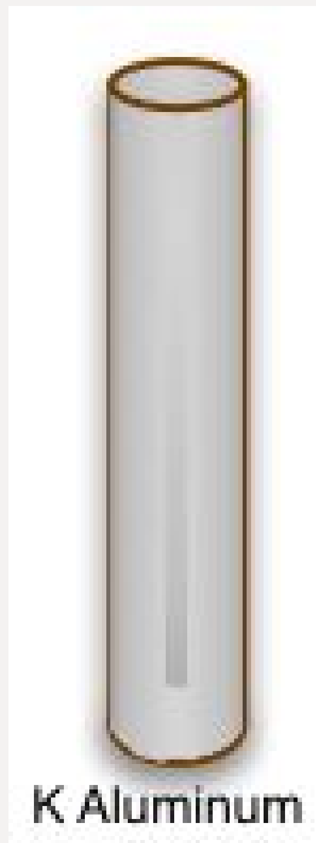
ow could **A and B have the same weight**?



Towards Density: 2
Weight, Size, & Heaviness of Materials

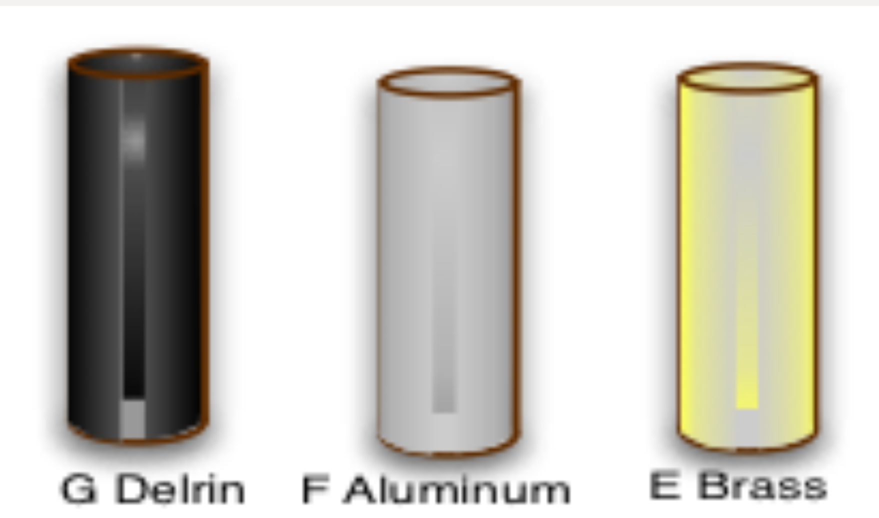
n each pair, Is one object made of a heavier material?

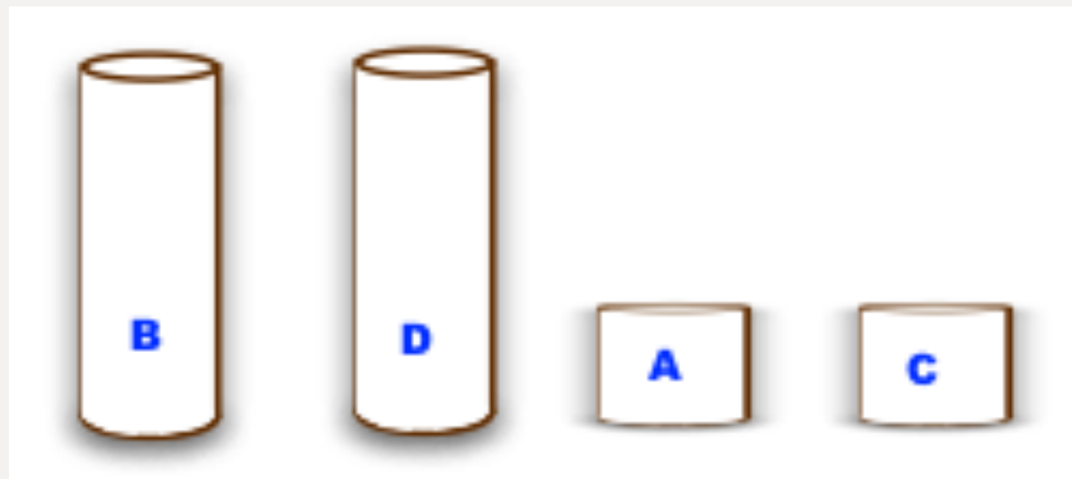




Weight, Size, & Heaviness of Materials

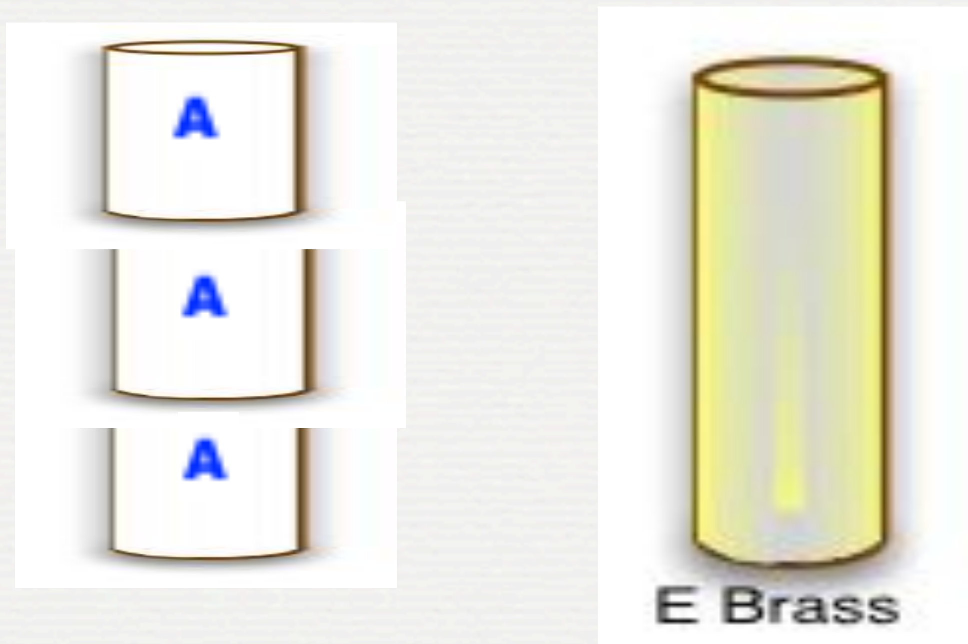
Part 3: What could B, D, A, and C be made of?





Stacking: Operating on Units

Do they spontaneously think to stack smaller cylinders to test hypotheses?

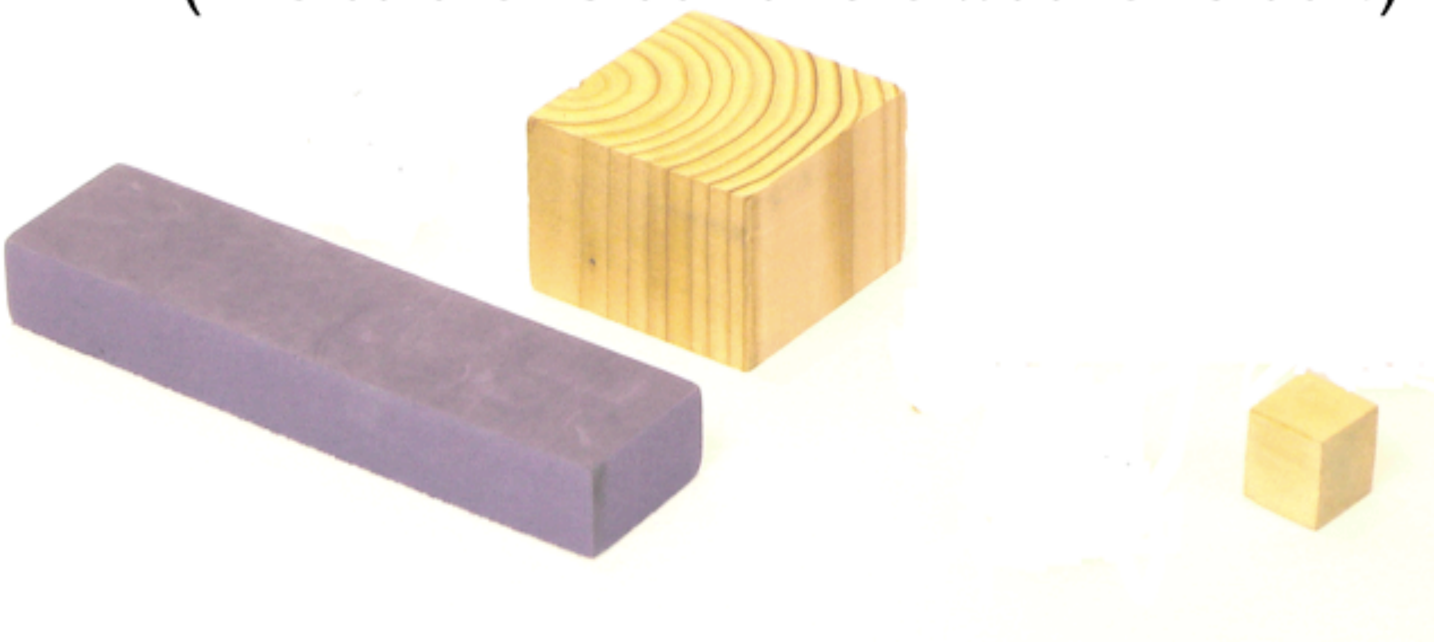


- **If the weight of A equals 1/3 the weight of E, the**
- **The weight of 3A’s should equal the weight of B**

Understanding Volume

Which is bigger? Which takes up more space?

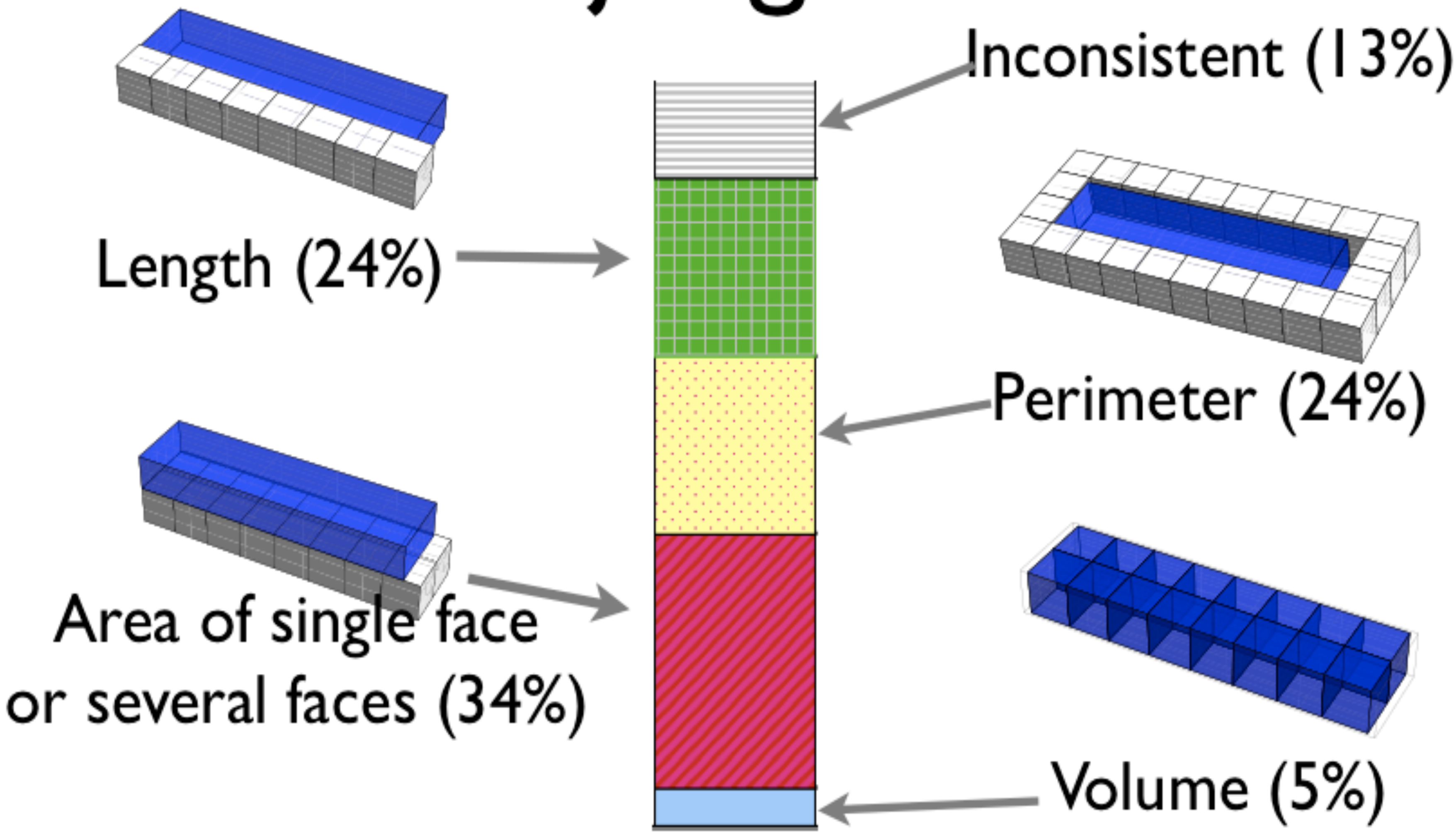
(The colored block or the wooden block?)



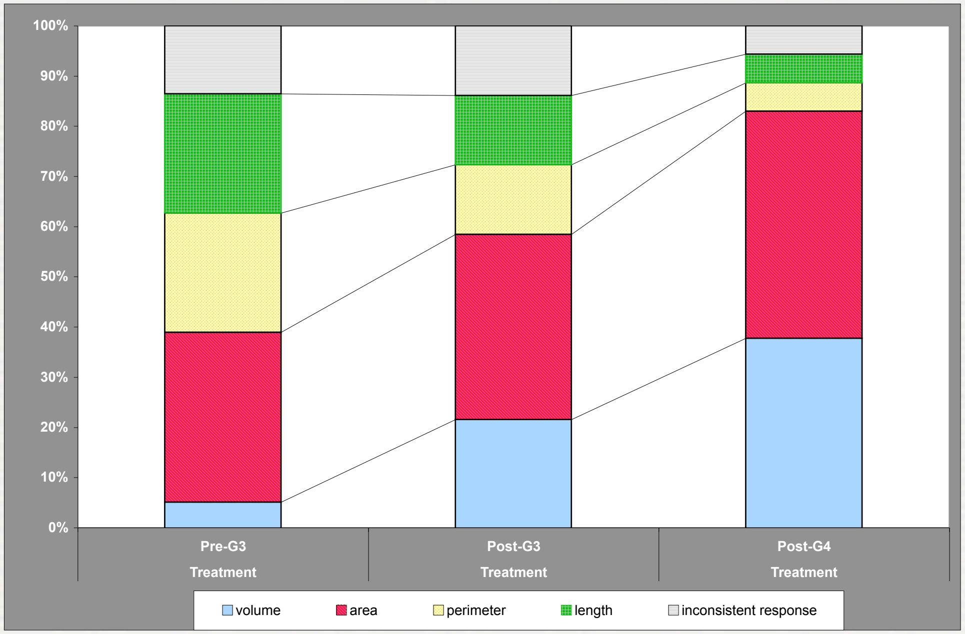
You may use the white cube to help you decide

Invariants

Third Grade Students base their judgment on

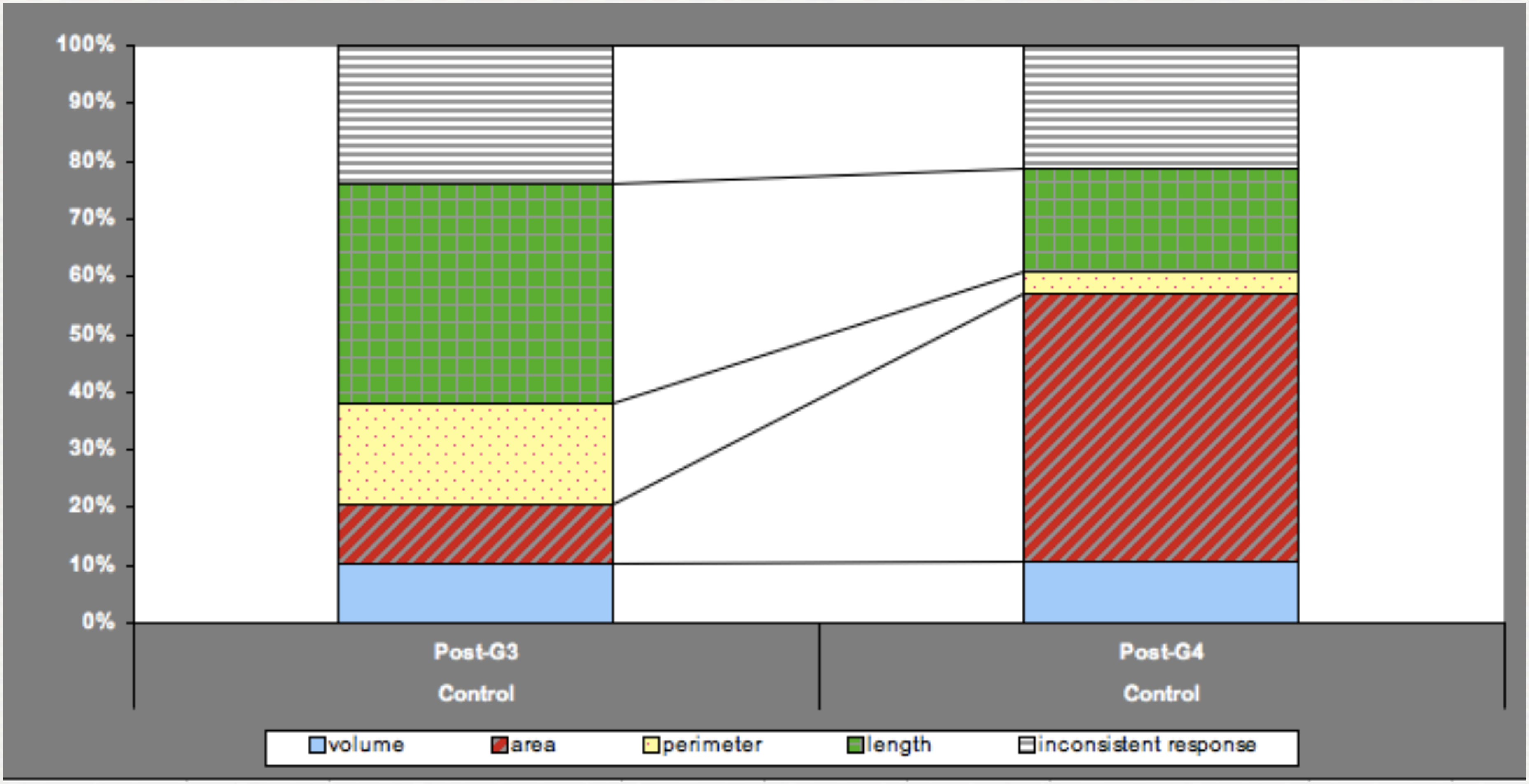


Volume over time: Treatment students



- Fewer measured Length or Perimeter
- More measured Volume

Control students



- Fewer measured Length or Perimeter
- More measured Area
- Volume stayed constant

Closing thoughts: Assessments designed to

Suit characteristics of the *population* (young students initially unfamiliar with technical vocabulary, units of measure, formulas...)

Monitor intra-individual changes over several years

Capture a variety of conceptualizations

In grade 3, teachers and the team were in doubt whether volume was too demanding a concept for 8-9 year olds. We realized from the interviews that there were several competing magnitudes that students were using for size and that much of the problem may consist in comparing and contrasting these and making clear which ones are being referred to.

On Specificity of Learning Progressions

Learning Progressions stress overarching themes, critical transitions, competing models, likely conceptual obstacles, unexpected interpretations, opportunities for investigation…

Specific embodiments and sequences of lessons ma vary widely within a single approach

Research about student thinking, and input from scientists, are ongoing components of LP work.