



NATIONAL ACADEMY OF ENGINEERING AND  
NATIONAL RESEARCH COUNCIL  
OF THE NATIONAL ACADEMIES

# STEM Integration in K-12 Education

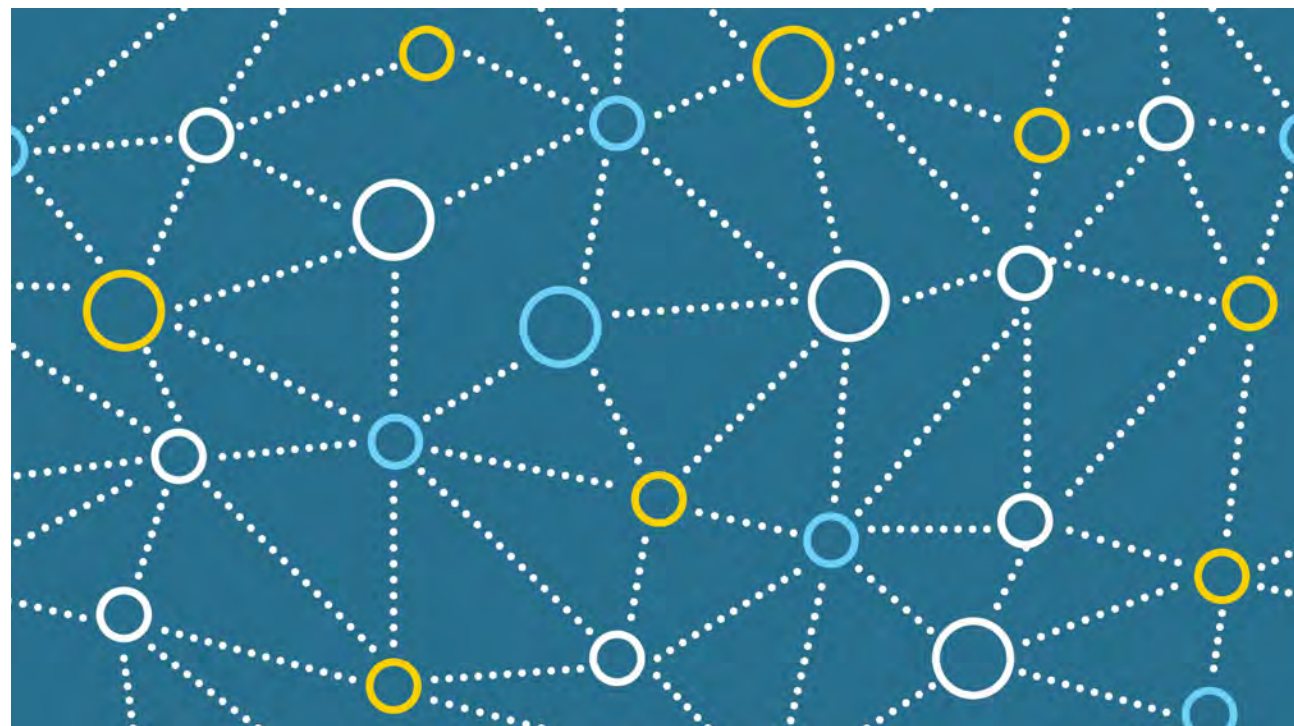
STATUS, PROSPECTS, AND  
AN AGENDA FOR RESEARCH



SILO



STEW



BRIDGES

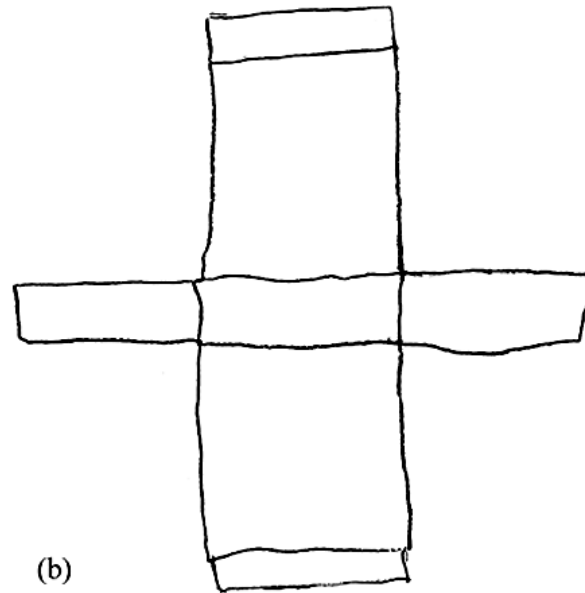


# Learning to Participate in Approximations to Disciplinary Practices

- Mathematics \“Common” Core Standards (US)
  - Look for and make use of structure.
  - Reason quantitatively.
  - Prove (convincing explanations about why).



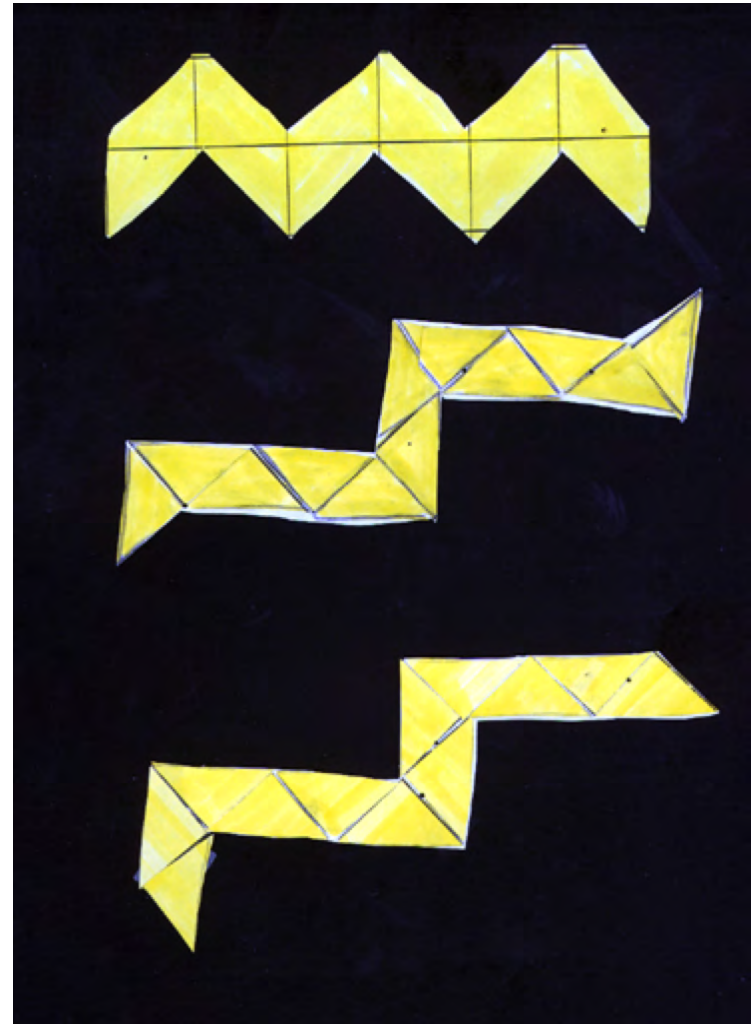
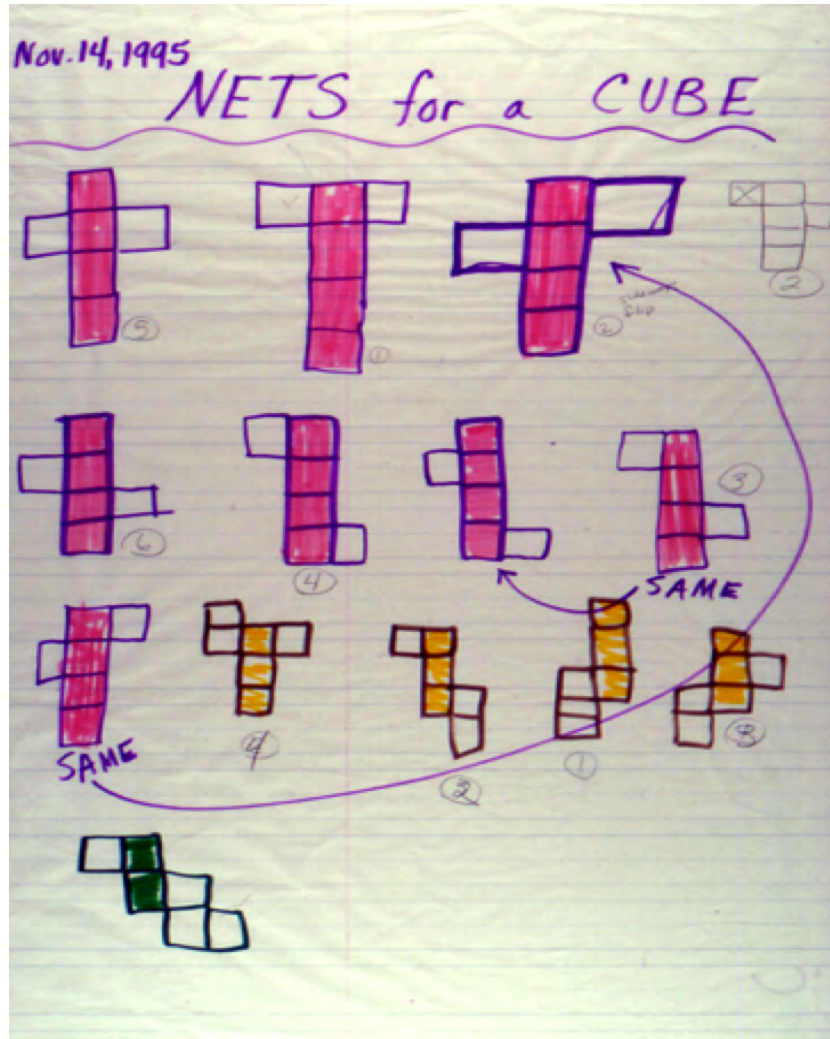
(a)



(b)

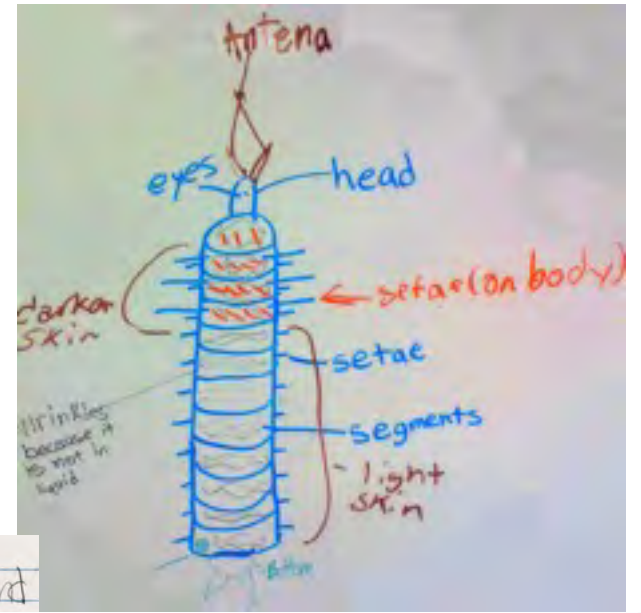
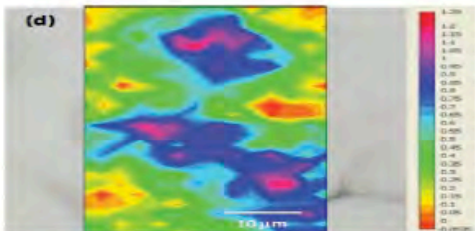
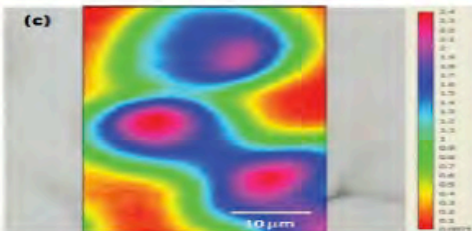
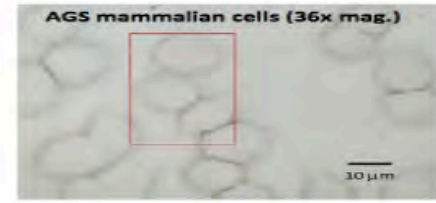
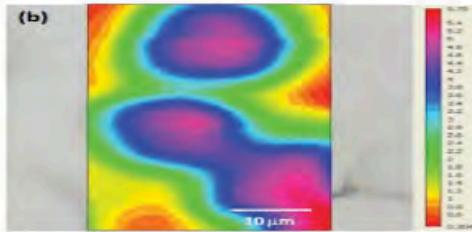
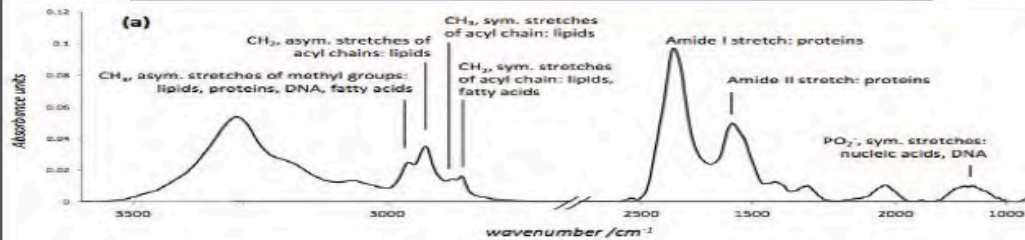


# Proving to Resolve Dispute: How many?

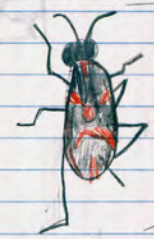


# Constructing Representations to Learn in Science

Russell Tytler, Vaughan Prain, Peter Hubber and Bruce Waldrip (Eds.)

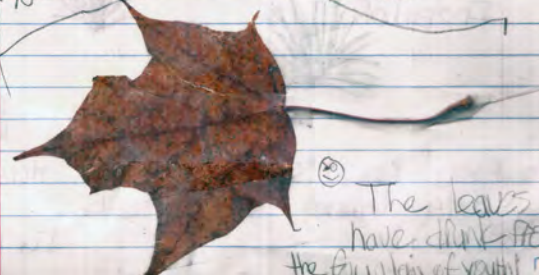


There is a strange bug on the door and it looks like this:



(front to tip of antenna) 1cm long

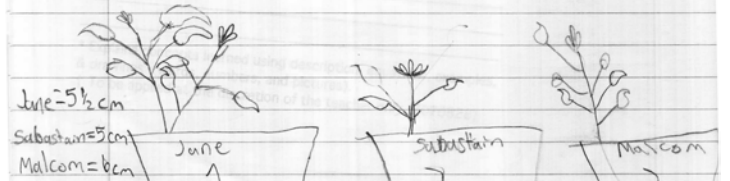
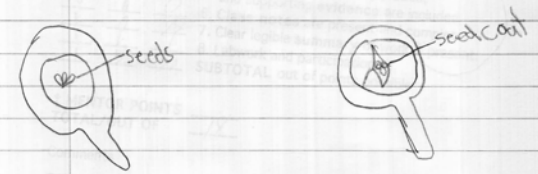
I isn't afraid of me, why is that? What is it? I'll call it the tick-o-ant bug. I think it's the small milkweed bug (*Lygaeus kalmii*)



The leaves have a thick skin the firm skin of rubber

dated April 1-2 4-08

plants. They move, I think it, Malcom was 5cm. Sabata's 5cm. Jane's 3 1/2 cm. They





# Modeling Nature

Science Education through Modeling Natural Systems

## Modeling

Inquiry

Concepts & Themes

Representational Fluency

## Curriculum Resources

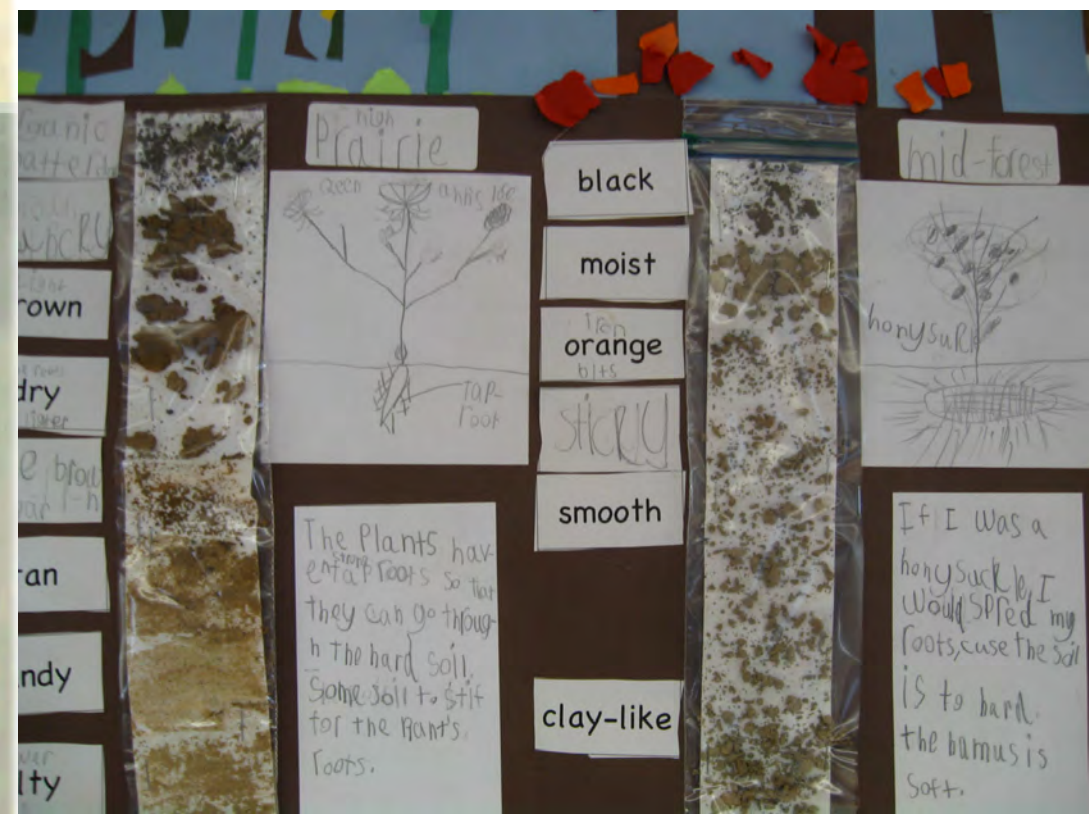
Investigating Growth of Organisms

Investigating Growth of Populations

Investigating Diversity

Investigating Behavior

Investigating Structure & Function



I was looking around my tree, on my tree was this piece of something green. My hypothesis is that it's fungi. I wonder why it grows and when?

Here's some of the supposedly fungi. This is a picture of how much there was on the tree and what it looks like.

When I was handling the "fungi" it felt easy to crumble.

It smells like bark on the tree.

I sometimes see ants on trees in my yard, maybe ants like the "fungi" for eating? I've seen this on other trees but I've never stopped to look and observe it.

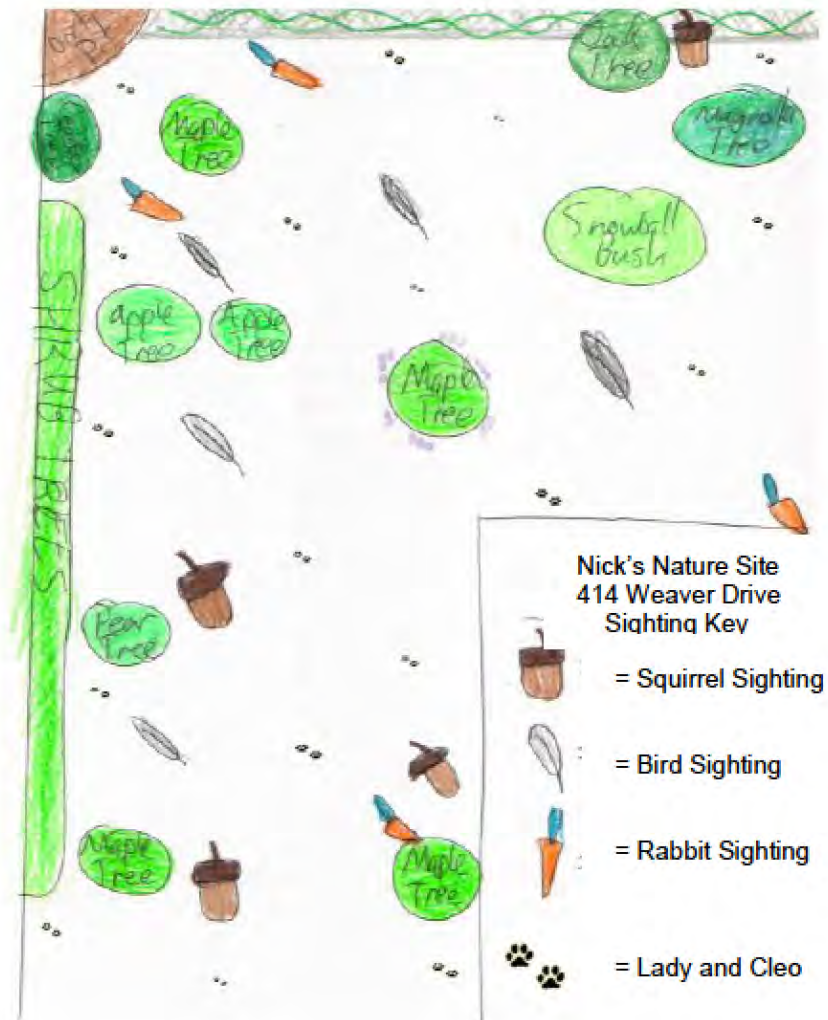


# NATURE in the CITY

By Nick "Tape" Posey

Over the past 34 weeks, I've had the opportunity to observe nature in the city. At first, I thought it would be hard to find. What I've learned is that if you just open your eyes and look, it's right there in front of you. I have a lot of birds and squirrels in my site. Occasionally, I've seen a rabbit or two. I haven't seen any snakes – thank you, Lord! I have some domesticated wildlife as well --two dogs.

There is a lot of plant life in my site, too, like trees, vines, weeds, and grasses. There is a bunch of nature in the city just waiting to be seen.





## Reflections (Grade 6)

I was able to do this article because I have been watching my NJ (nature journal) site. I had a lot of fun watching my site and writing down information about it. **You should try watching a site for a long period of time! You will be able to see how things change** through out the seasons of the year. If you pay attention you notice that things are different in spring, winter, fall, and summer. For example in my site during the winter my humming birds migrate. During the spring my RTHB (ruby throated humming birds) come back and stay till it get cold again in the winter. Also you will notice that during the winter the squirrels don't come out as much and neither do the (normal) birds.

-- Kayla

SUMMER

HAWKON

EDITION



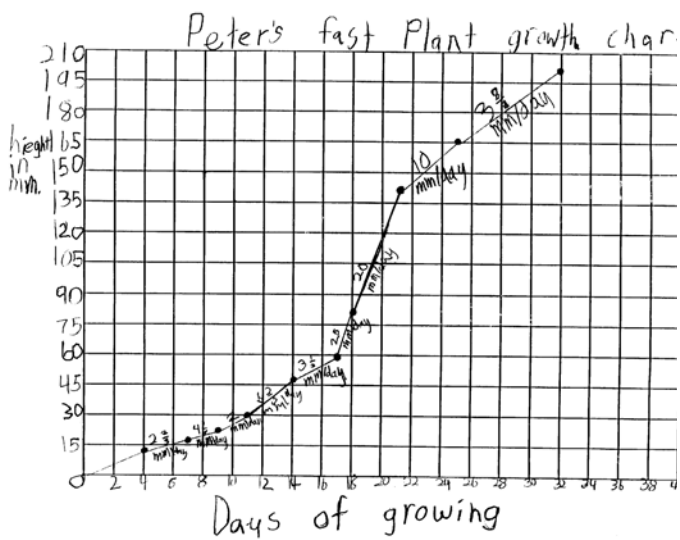


EVERYMANDUCAN

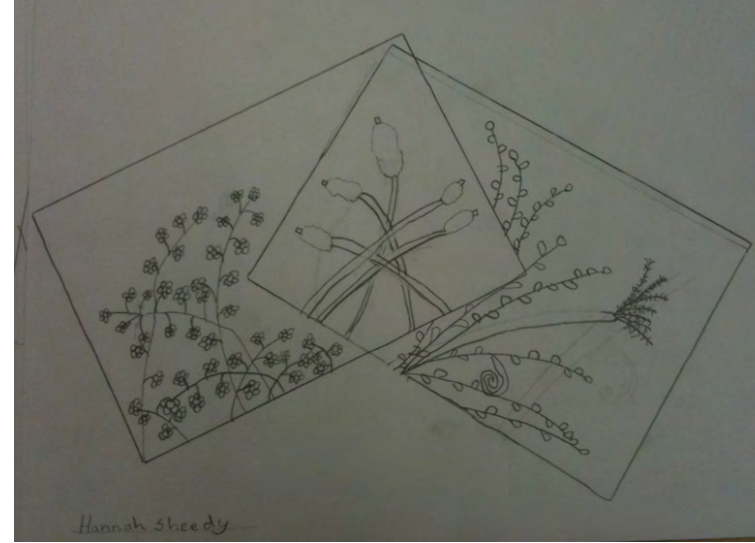


# Integrated STEM Education

- Cultivate Interest and Identity
  - Project-based learning provides opportunity to trigger and then cultivate interest
  - Expands the reach of STEM to under-represented populations
- Prospects for Cross-Cutting Practices and Concepts Across Disciplines
  - Design, Trigonometry, Dynamics and Kinematics, Technology
- But Students Often Don't See or Experience as Intended
  - Stew?



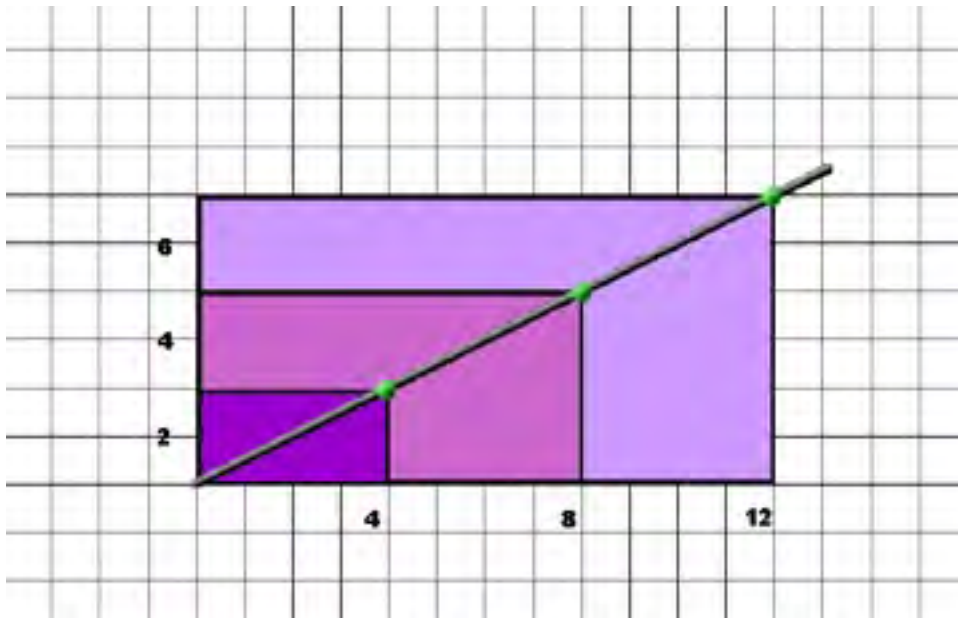
# BRIDGING



- Preserve Disciplinary Practices but Establish Resonances Among Them
  - Concept-Practice is amplified/elaborated by involving multiple disciplines.
- Sustain Opportunities for Triggering and Cultivating Interest
  - Connect in some way to ongoing cultural practices discernable to children.
  - And/or provide avenues where interest can be cultivated and sustained over time.

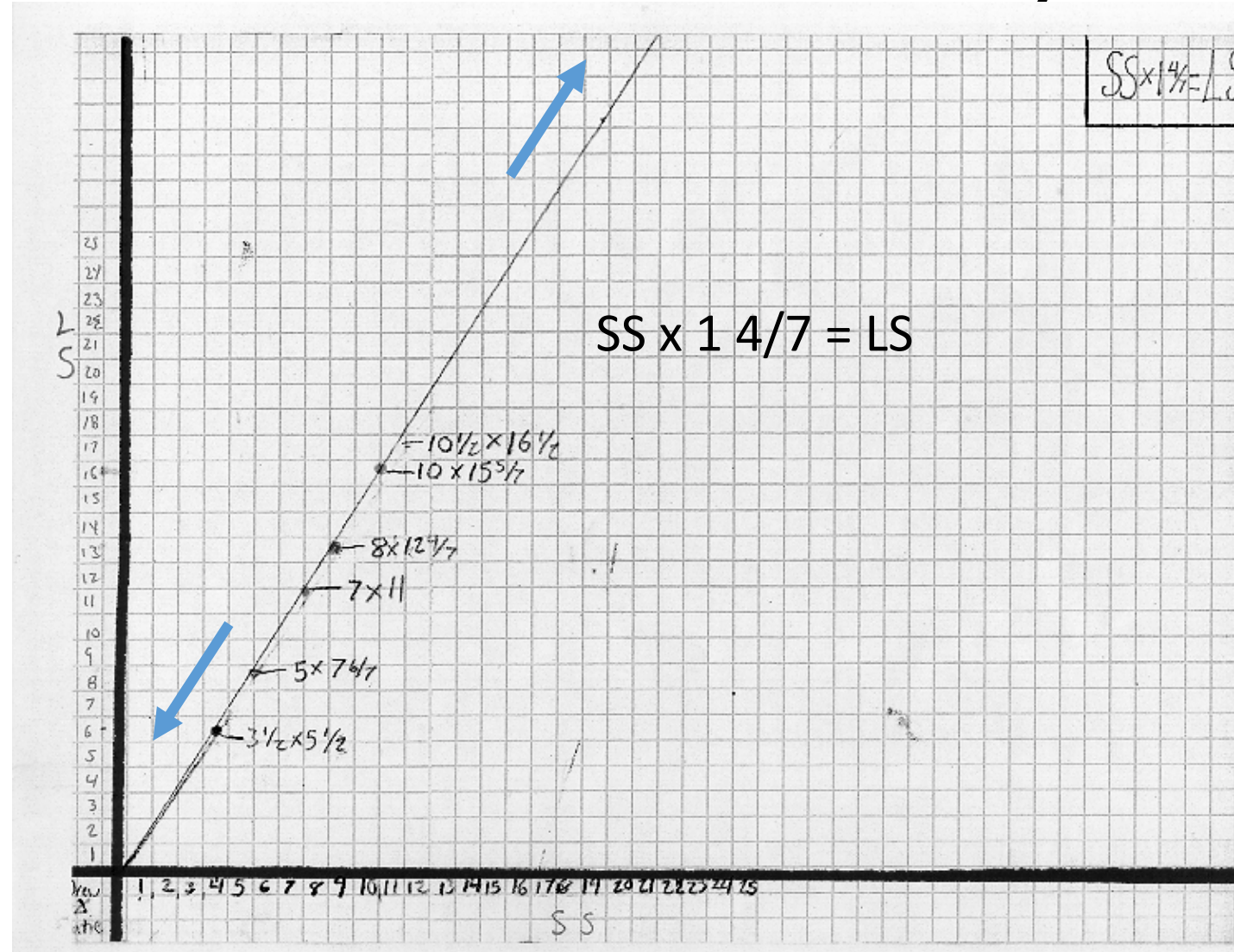
# Mathematical Investigation: Same Shape?

- Paper Cut-outs of Rectangles in Different Ratios of Long Side to Short Side (e.g., 2:1, 4:3)
  - Initial focus on equivalence (sort into groups and tell why)
- Subsequent Focus on Similarity as Constant Ratio of Measures

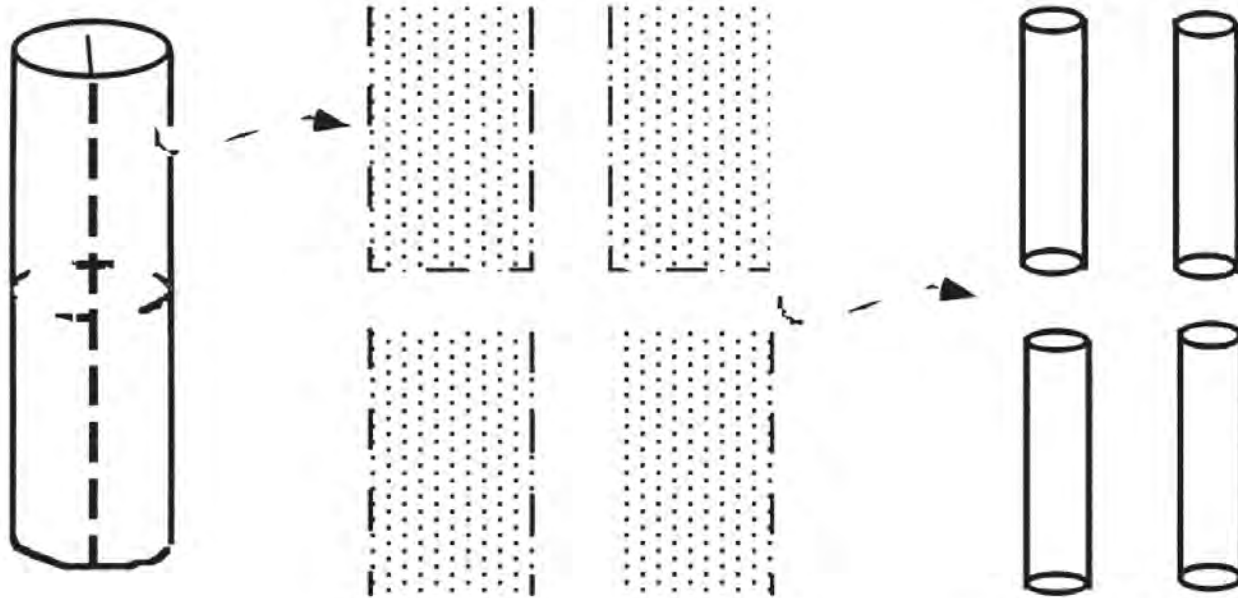


- Literal Scaffold for 2 x 4, 4 x 8, 6 x 12
- Measure Scaffold, Multiple Zero points?
- One point stands in for rectangle
- $LS = 2 \times SS$
- $LS \times \frac{1}{2} = SS$

# Generalize to "Family"

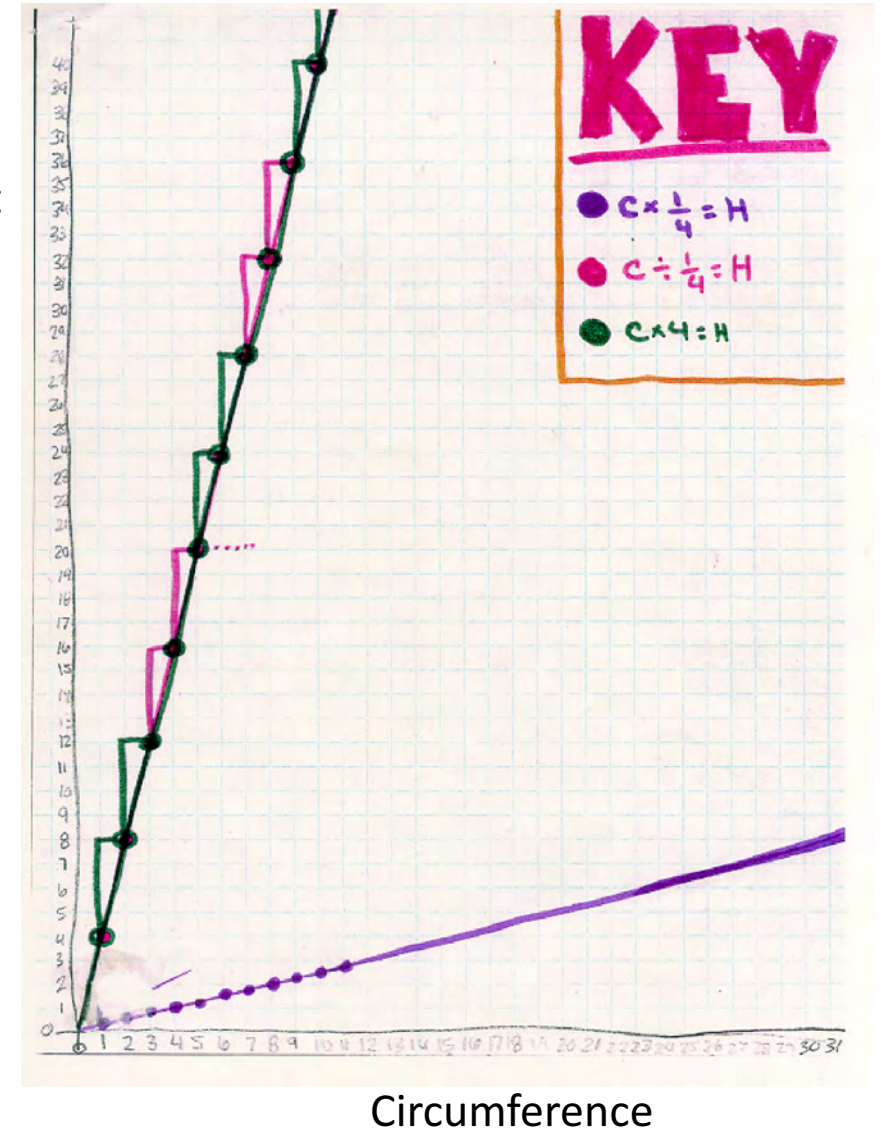


# Extension to Cylinder C:H



Height

Scale Factor Interpretation (1/2)

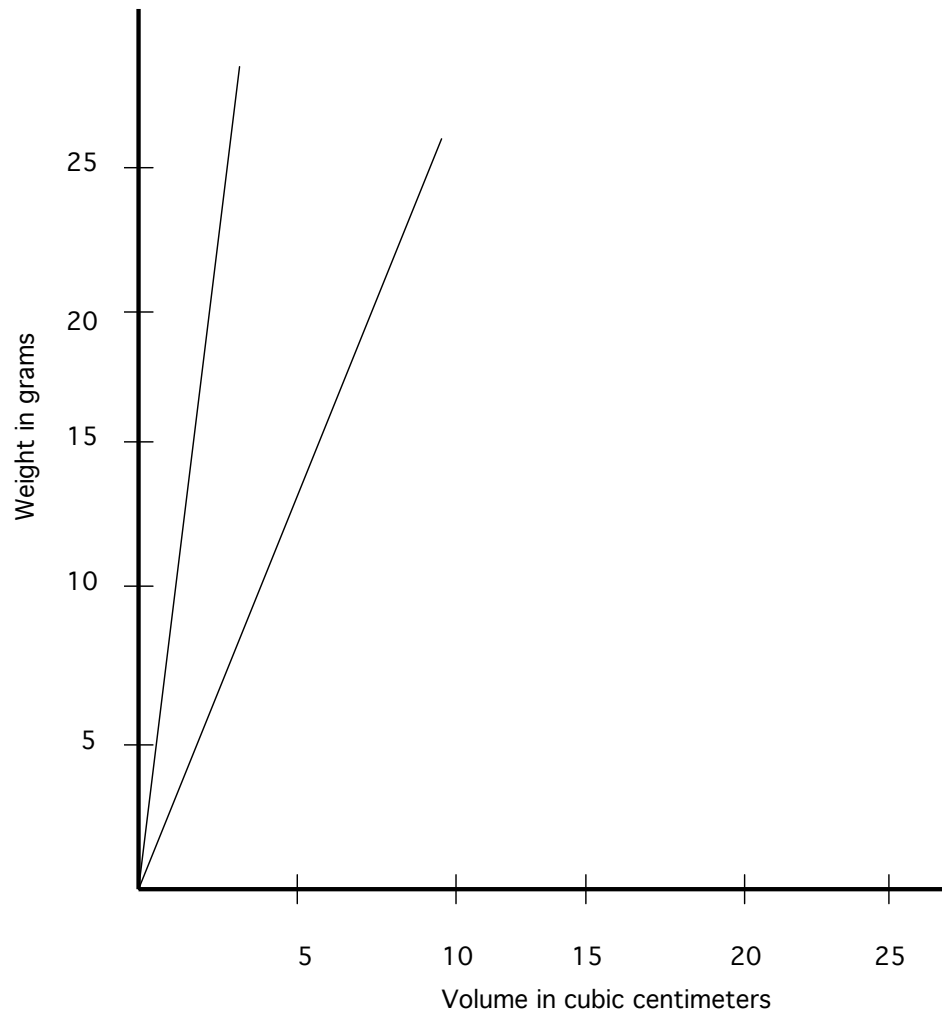




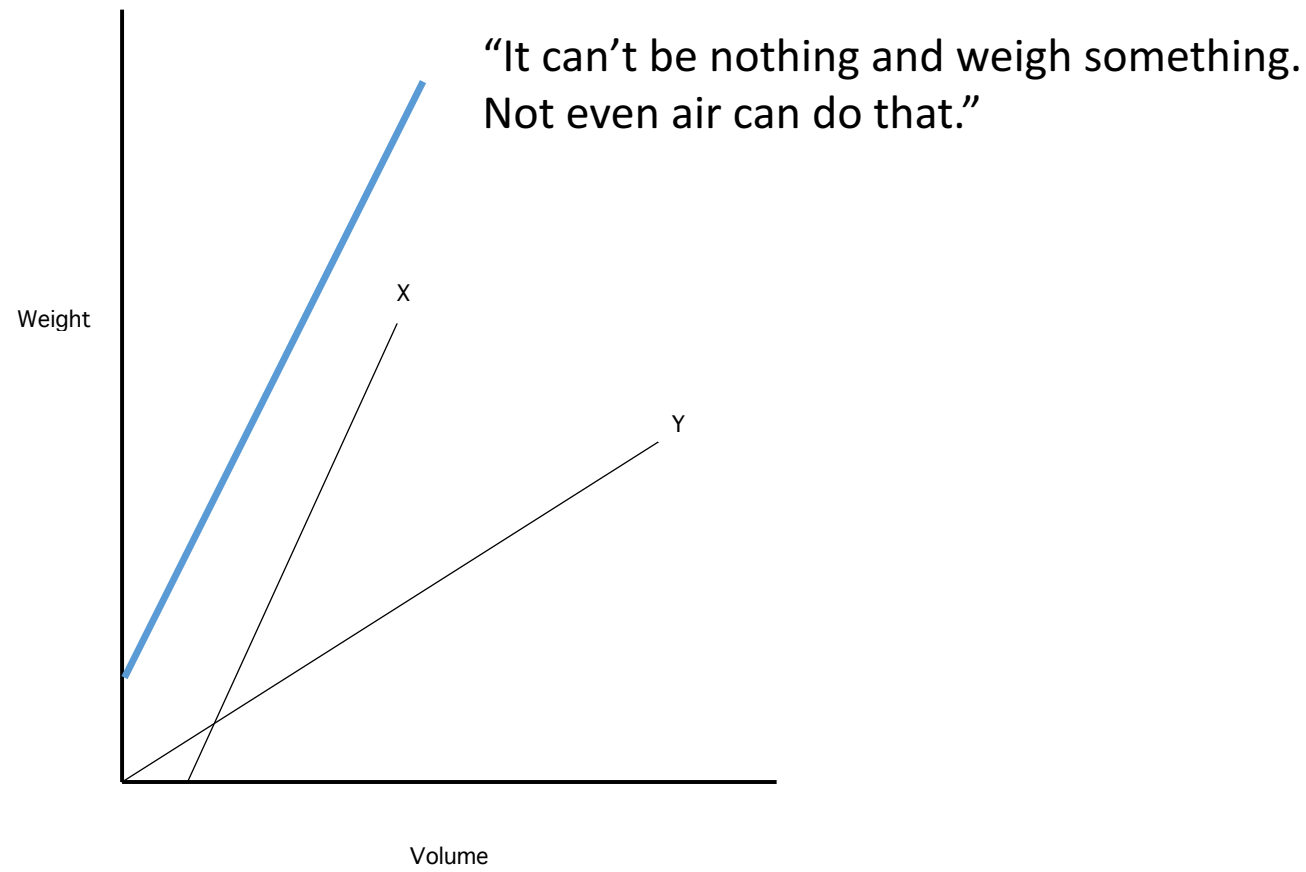
# Model for Material Kind

- Stuff made of brass, Teflon, wood, styrofoam and in different sizes and shapes (cubes, rectangular prisms, cylinders, spheres)
- Rank order by weight, volume
- Families like LS:SS or C:H?

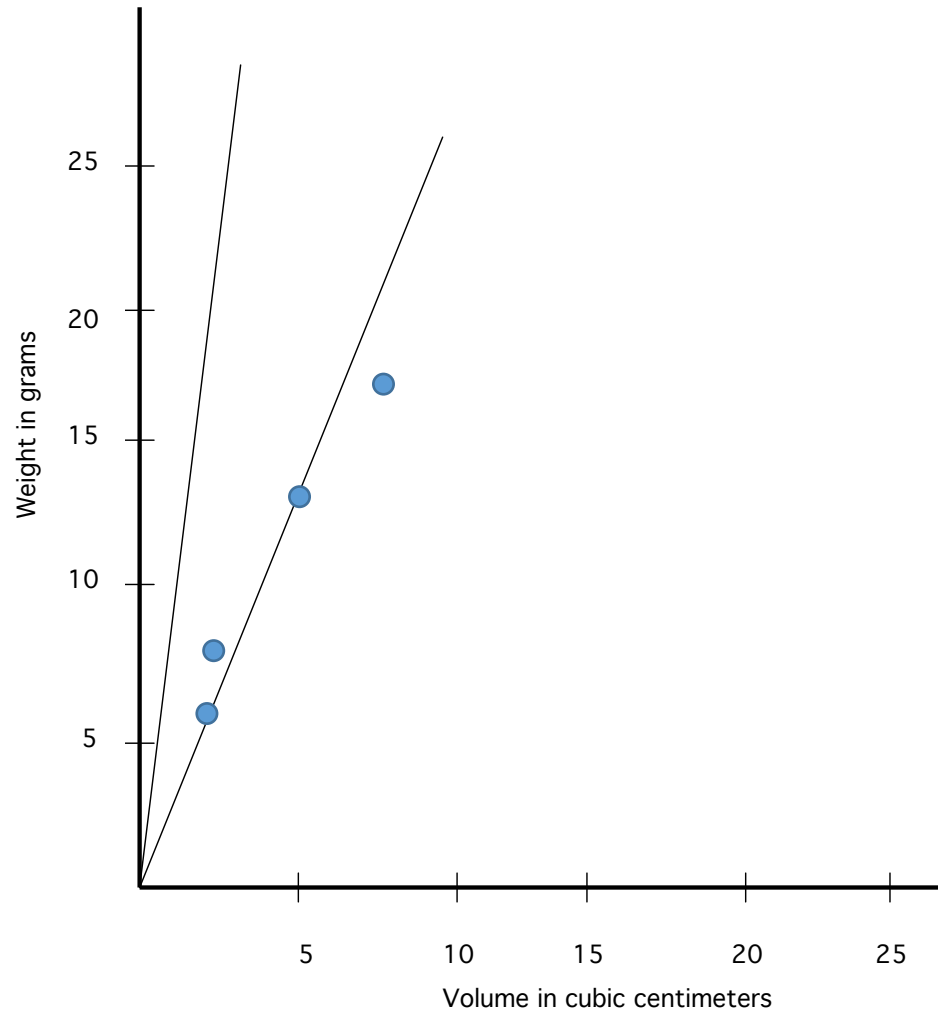
What does steepness mean here?



Physically Intelligible?



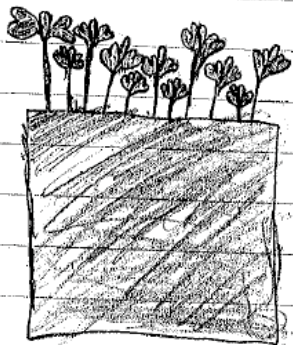
# Different Families or Measurement Error?



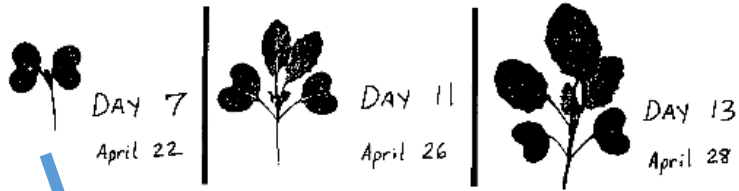
‘We can’t tell for sure. It might be that they are fooling us and they just feel and look the same [points to researchers]. But I don’t think so. It’s likely that it’s because we could measure some [gestures to prisms] better than others [taken as shared that sphere and cylinder measures were more variable].’

# Modeling Growth: Circulating Reference

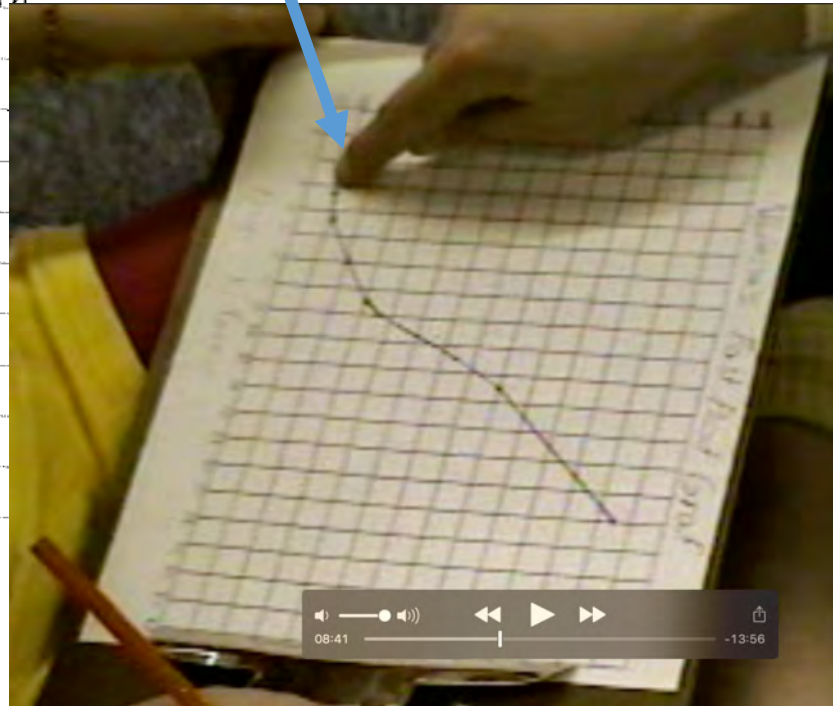
Today Area 1, 2, 3, and 4 all have true leaves. They are very beautiful. On the stem they are hairy. There is something on area 4. What could it be? It is very small and it look like an egg. Could it be an egg? It has a white dot in the middle.



## Fast Plant Growth



Steepness means?



# Piece-wise Linear Growth

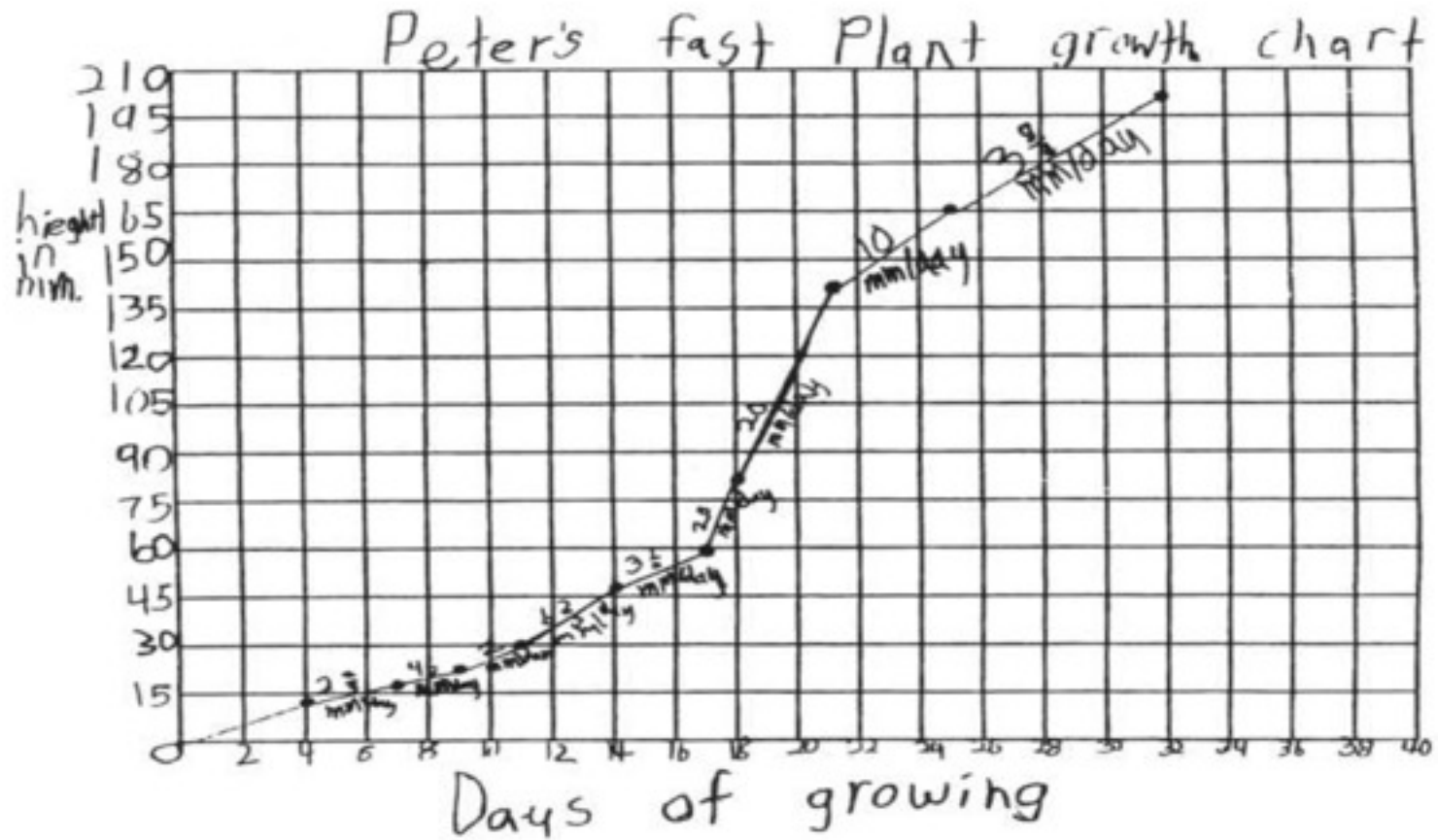
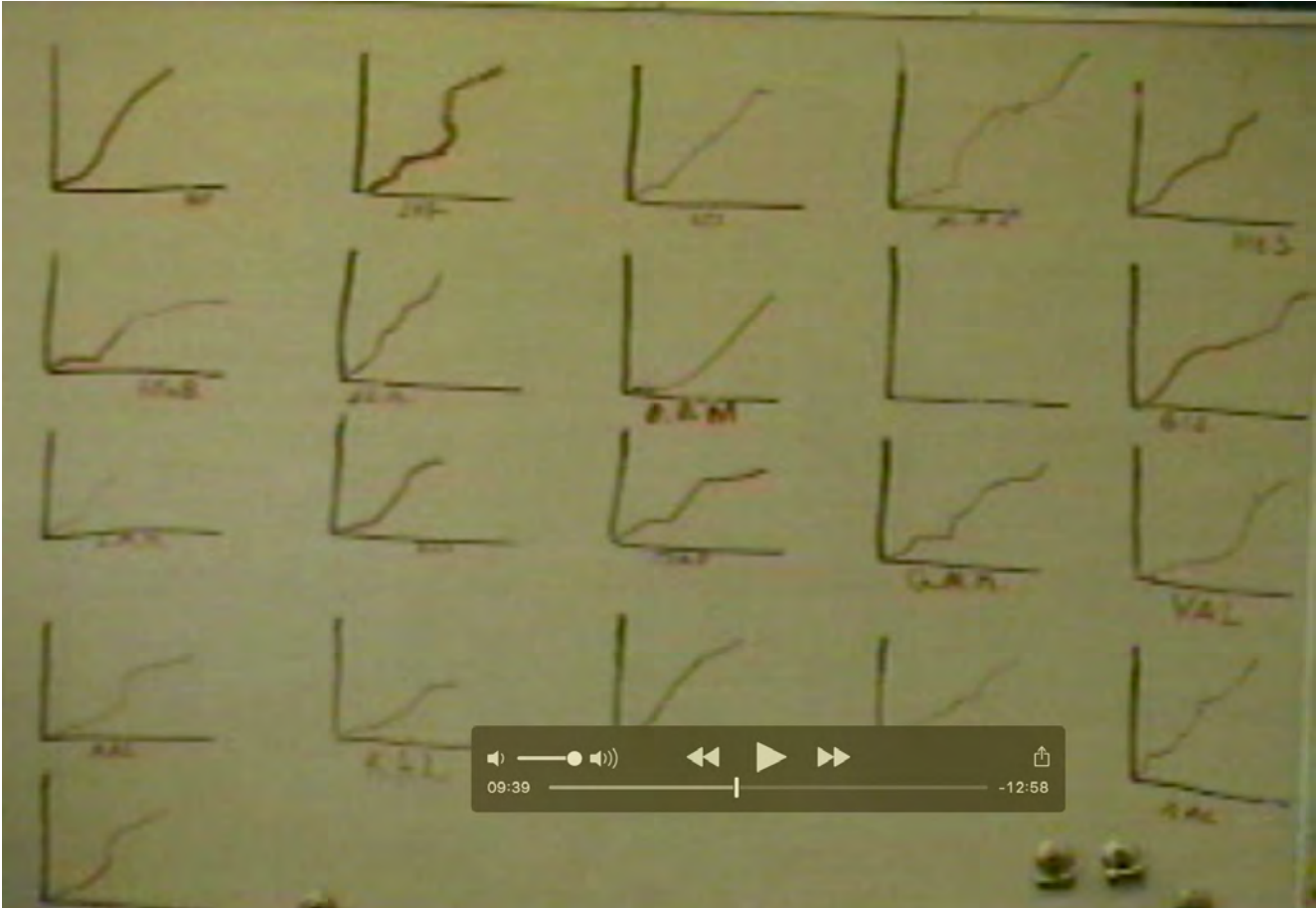
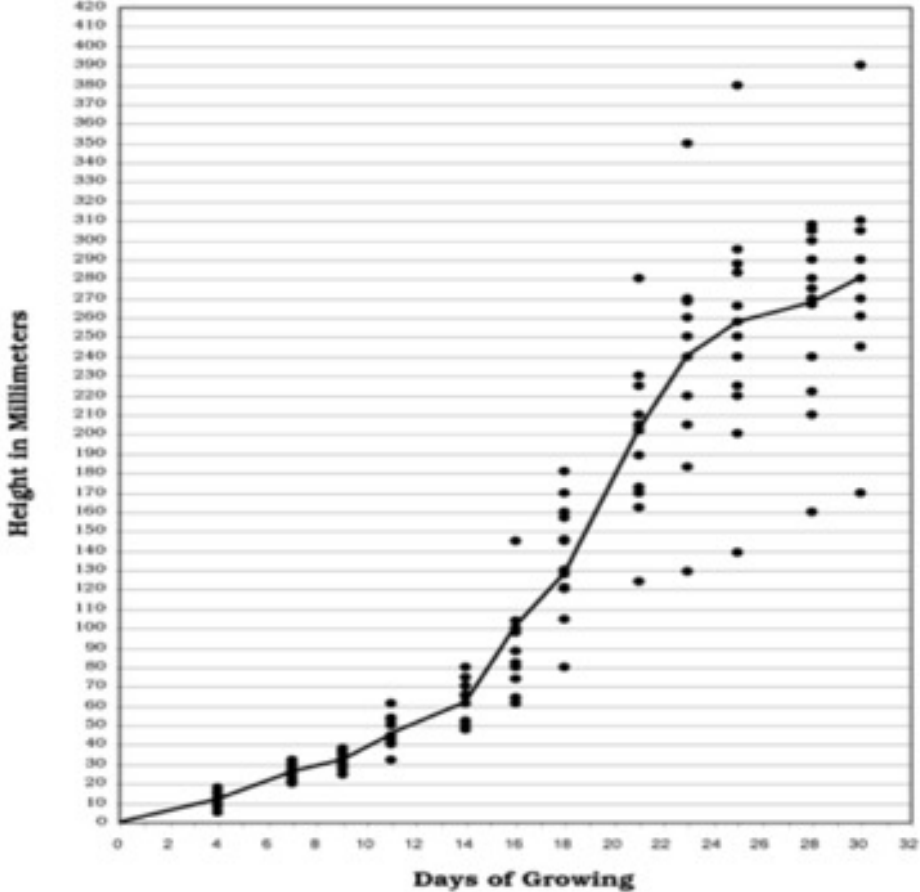


FIG. 9.10. Growth curve annotated with rates of growth in millimeters per day.

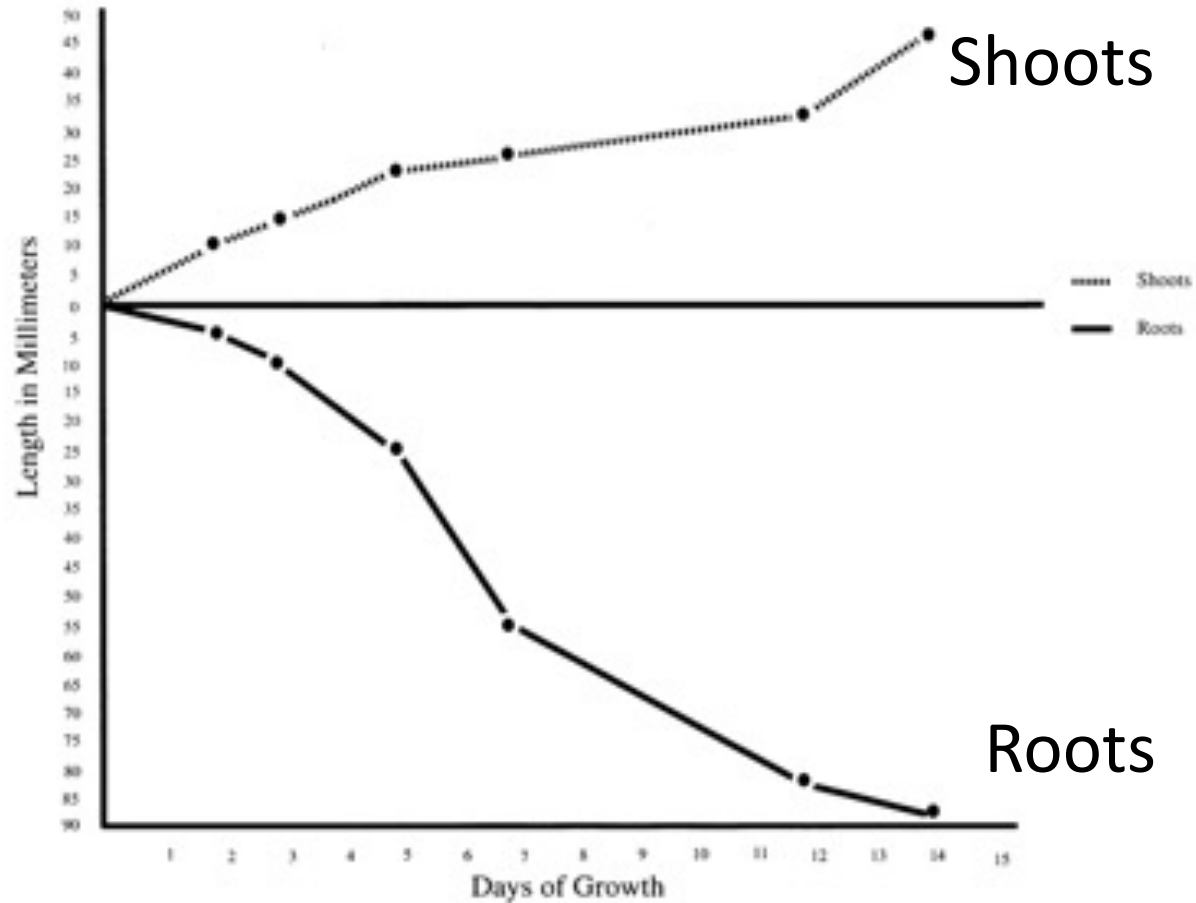
# Prototypical Growth: Need Every Point Refer to a Particular Plant?



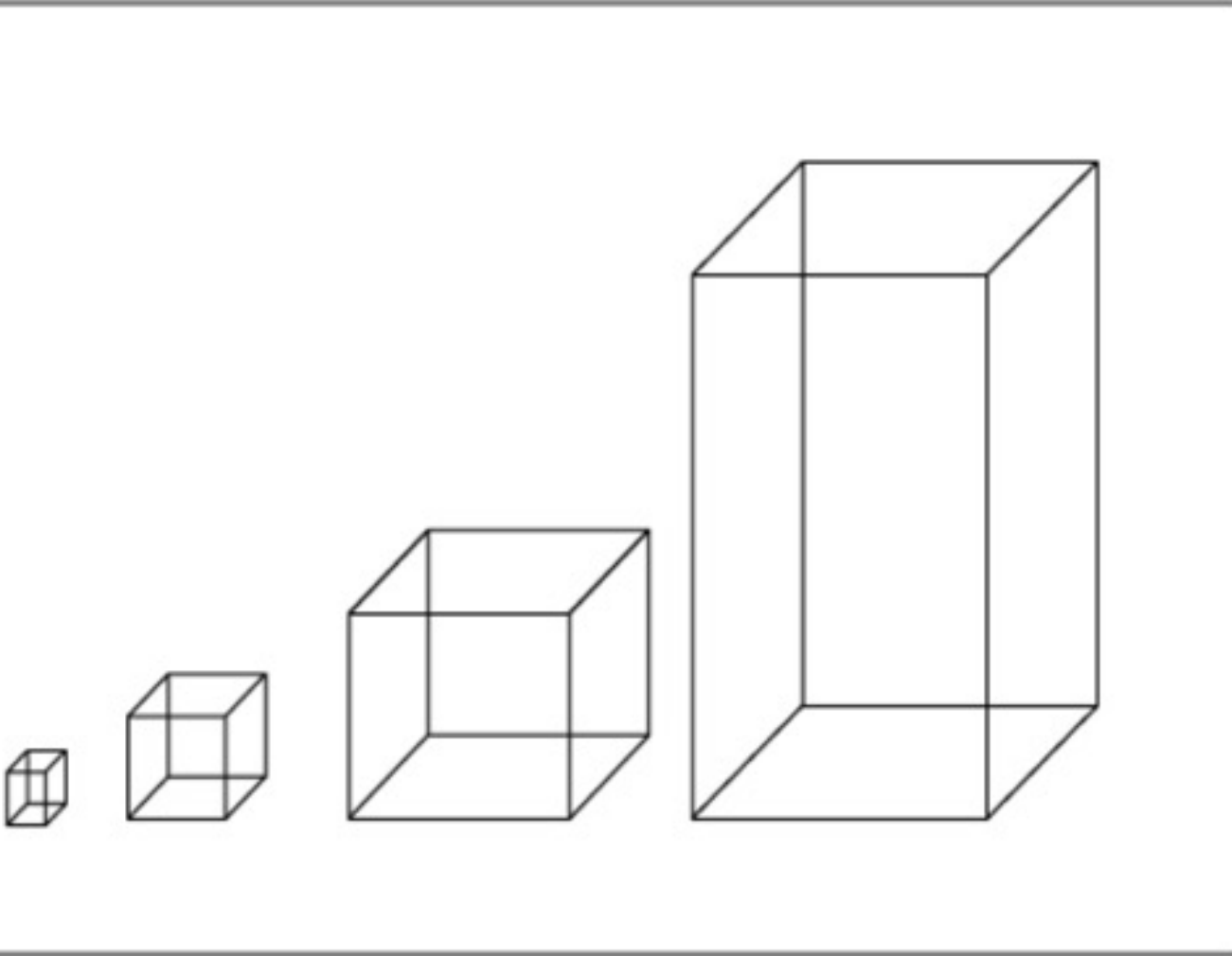
Height of Round Two Fast Plants  
( 6 pellets fertilizer)



# Re-purpose Cartesian Coordinate System



# Volume of Canopy



Cylinder?

- Width = max (leaf tip to opposite leaf tip)
- Cut rectangle where diameter of corresponding cylinder = Width?
- Construct circles, measure diameter, circumference
- “It’s about  $3 \frac{1}{5} \times W$ ”



# Lessons Learned about Designing for Integration

- Re-visioning Relations Among Disciplines to Increase Likelihood of Resonances between Them
  - Junctions between disciplines, not “always integrated.”
- Taking a Longitudinal View
  - What are the prospects of using newly learned ideas/practices of knowing as resources in future learning?
- Considering How Teachers can Support Student Thinking
  - Identifying some typical forms of students’ thinking and making that visible

Lehrer, R. & Schauble, L. (2015). Developing scientific thinking. In L. S. Liben & U. Müller (Eds.), *Cognitive processes*. Volume 2 of the *Handbook of child psychology and developmental science* (7th ed.). Editor-in-chief: R. M. Lerner. Hoboken, NJ: Wiley.

Lehrer, R., & Schauble, L., (2012). Seeding evolutionary thinking by engaging children in modeling its foundations. *Science Education*, 96(4), 701-724.

Lehrer, R., Schauble, L., & Lucas, D. (2008). Supporting development of the epistemology of inquiry. *Cognitive Development*, 24, 512-529.

Lehrer, R., Strom, D., & Confrey, J. (2002). Grounding metaphors and inscriptional resonance: Children's emerging understanding of mathematical similarity. *Cognition and Instruction*, 20, 359-398.

Lehrer, R., & Schauble, L. (2002). Symbolic communication in mathematics and science: Co-constituting inscription and thought. In E. D. Amsel & J. Byrnes (Eds.), *Language, literacy, and cognitive development. The development and consequences of symbolic communication*. (pp. 167-192). Mahwah, NJ: Lawrence Erlbaum Associates.

Lehrer, R., Schauble, L., Strom, D., & Pligge, M. (2001). Similarity of form and substance: Modeling material kind. In D. Klahr & S. Carver (Eds.), *Cognition and instruction: 25 years of progress*. (pp. 39-74). Mahwah, NJ: Lawrence Erlbaum Associates.

**We call this the "Z pod" of nets in the "three in a row group", which is another group in the "family" of two-triangle nets for a cube.**

