Improving Mathematics and Science Education: Making Change Work

Deborah Loewenberg Ball

University of Utah • October 8, 2009

SCHOOL OF EDUCATION UNIVERSITY OF MICHIGAN

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The problem

- American youth are outperformed in mathematics and science by their peers in other developed nations.
- Opportunities to learn and achievement outcomes are stratified by race and class.
- Mathematics and and science curricula are not coherently organized, internally or systemically.
- Teachers are underprepared in mathematics and science.

- **This is not a new problem.**

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What should be the goal?

1. For all students, **reliable access** to high quality mathematics and science instruction no matter who they are or where they live.
2. Higher levels of **achievement** by all students.
3. The elimination of the **achievement gaps** between underrepresented minority students and students living in poverty and their white and middle class counterparts.
4. Commitment by the country to the importance of the mathematics and science education of all students, as demonstrated by the allocation of human, fiscal, and social and political **resources** to create the capacity needed to attain these standards.

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Typical solutions

- Write standards.
- Produce new curriculum materials.
- Create incentives to recruit and retain mathematically and scientifically skilled teachers.
- Provide professional development.

➢ **None of these is wrong.**

➢ **But none of these is sufficient to solve the problem, either.**

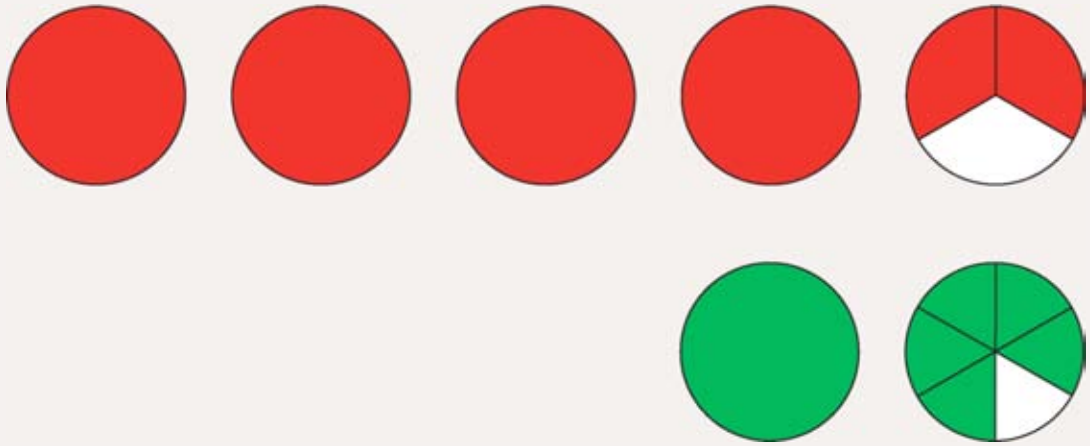
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Taking a closer look: What is involved in delivering high quality mathematics or science education?

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Modeling $-4\frac{2}{3} + 1\frac{5}{6}$

- Red "pies" to represent negative numbers
- Green "pies" to represent positive numbers



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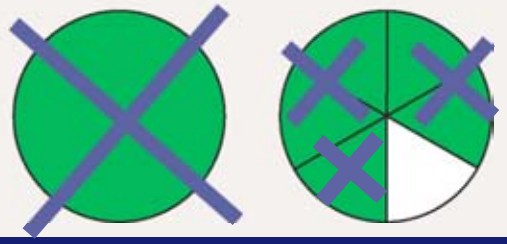
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Modeling $-4\frac{2}{3} + 1\frac{5}{6}$

- Red "pies" to represent negative numbers
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Answer: $-2\frac{5}{6}$



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Teaching conversion of units of measure

- How many decimeters are there in 5 meters?
- How many centimeters are there in 3 meters?
- How many centimeters are there in 8 decimeters?

Task: Measuring line segments with lengths of 9 cm and 12 cm

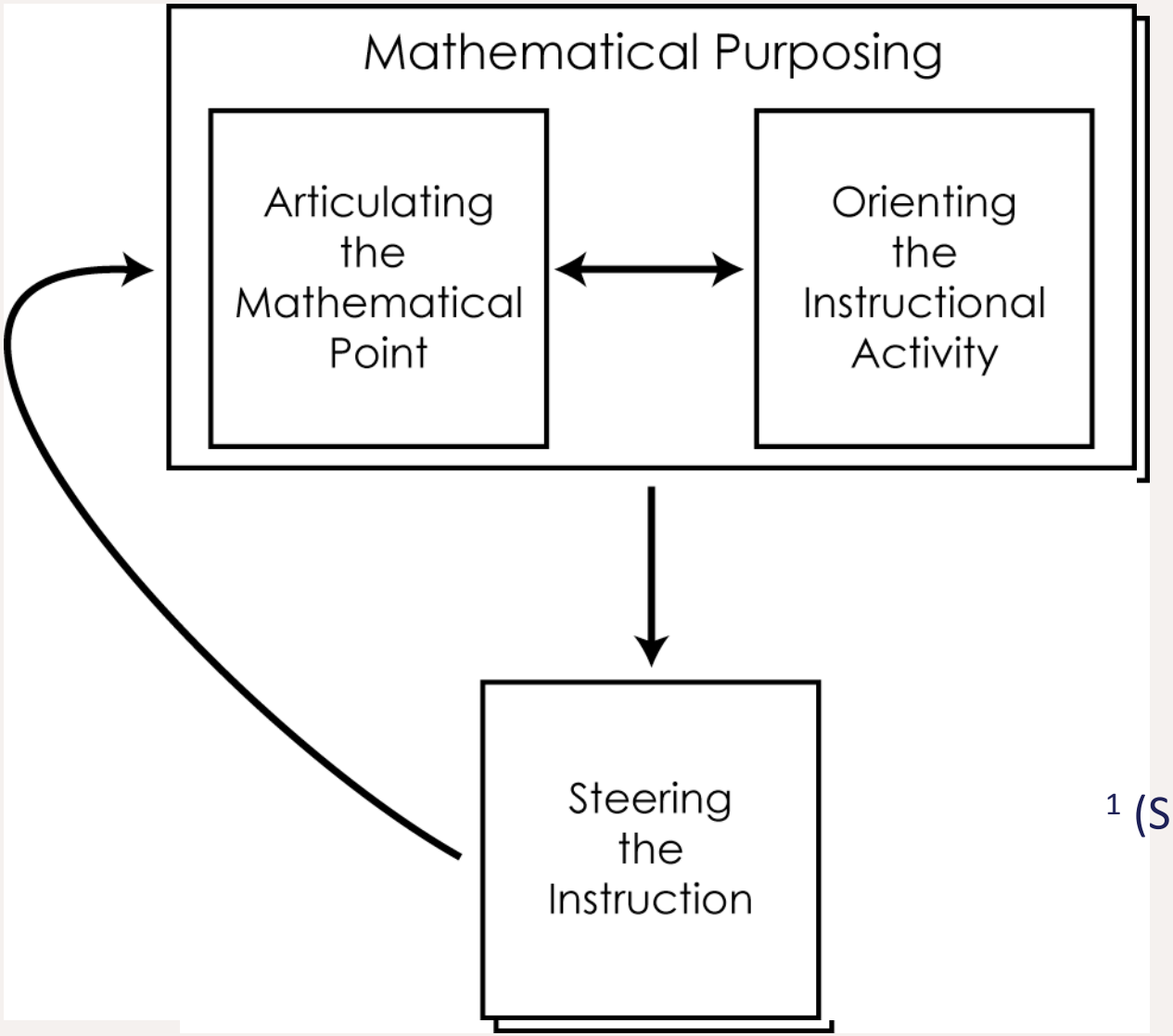
Spontaneous add-on: Convert the centimeter measure to decimeters, meters, and millimeters.

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Teaching to the mathematical point[1]



[1] (Sleep, 2009)

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Problems in steering instruction toward the mathematical point[1]

- Attending to and managing multiple purposes
- Spending instructional time on *mathematical* work
- Spending instructional time on the *intended* mathematics
- Making sure *students* are doing the mathematical work
- Developing and maintaining a mathematical storyline
- Opening up and emphasizing key mathematical ideas
- Keeping a focus on meaning

[1] (Sleep, 2009)

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Making change work for high quality mathematics and science education: Three essential components

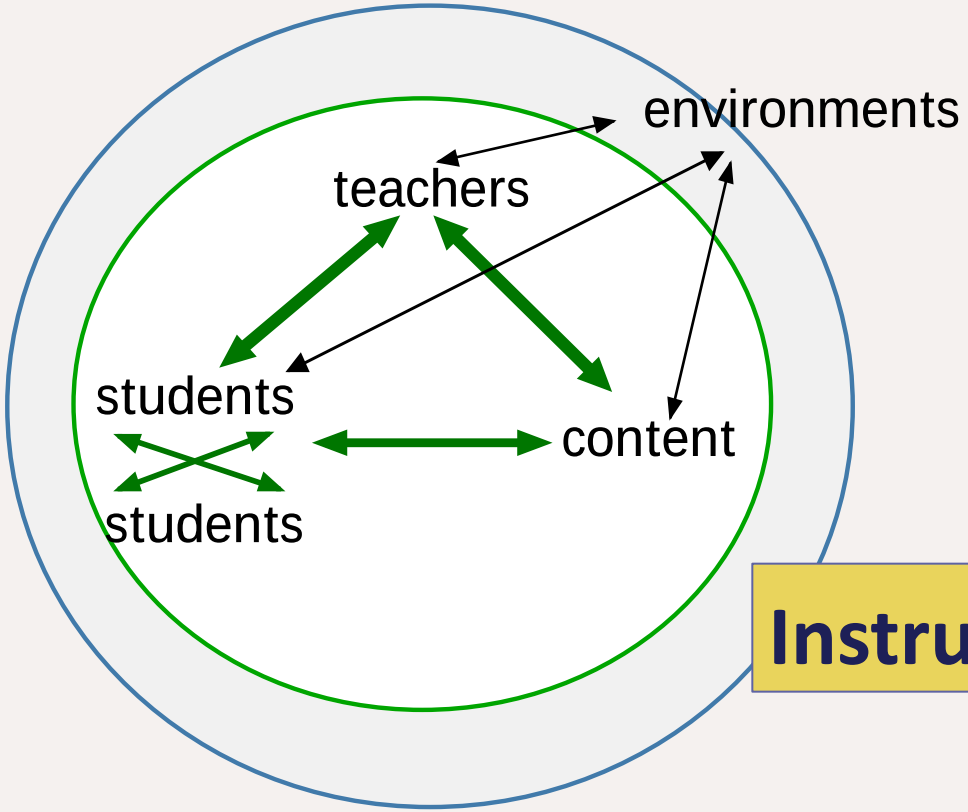
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What persistently impedes progress?

1. Persisting with extinct arguments about skills versus conceptual understanding
2. Lack of a central or common curriculum
3. Persisting with outdated and refuted ideas about "teacher quality," especially with respect to content knowledge
4. Persisting with pendulum shifts from teacher-proofing to teachers, but rarely focusing on teachING
5. Persisting with approaches to teacher education that emphasize things other than practice (e.g., reflection, beliefs, propositional knowledge, experience)

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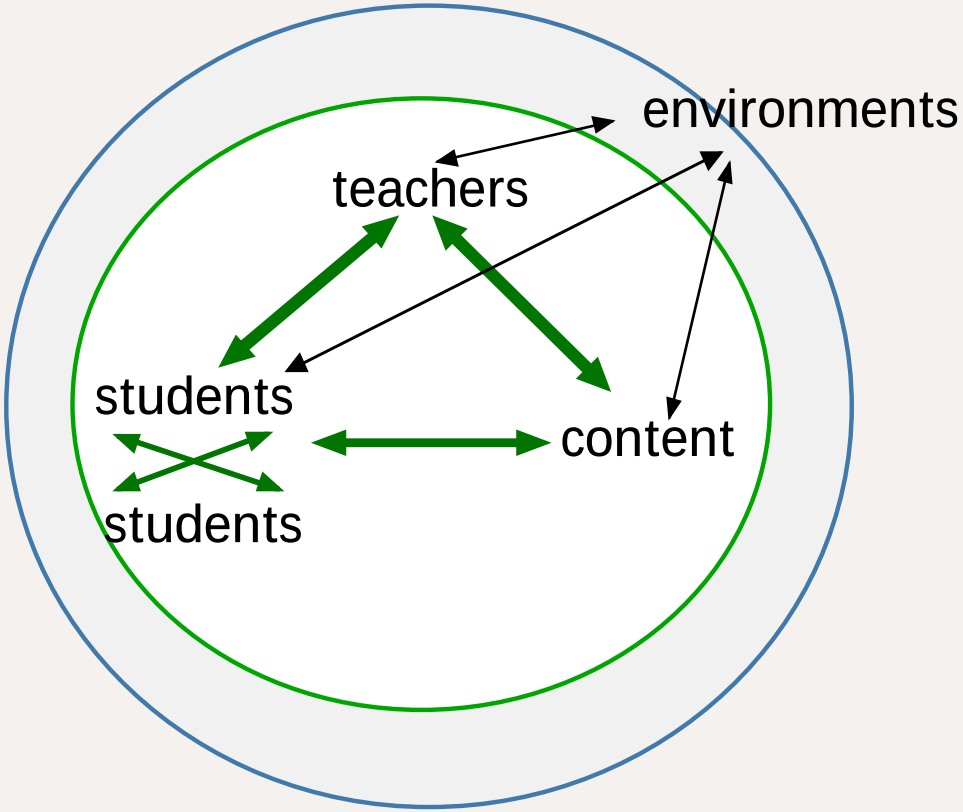
What have we learned that could enable real progress?



Instruction is key.

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1. Keep instruction central



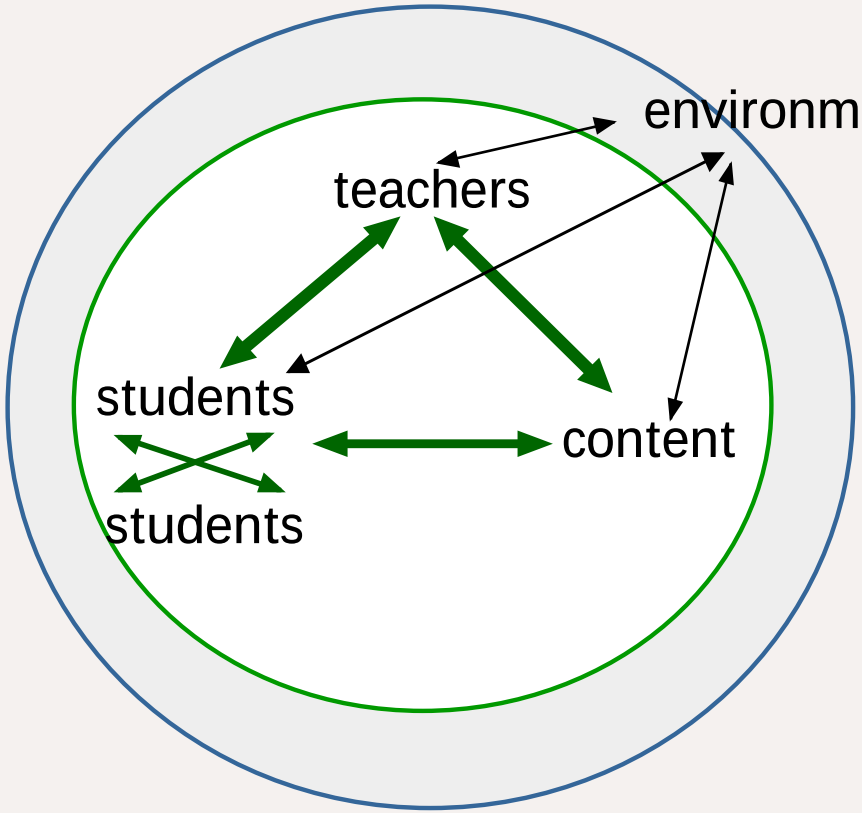
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What are constituents of high quality instruction?

- Coherent curriculum
- Supportive learning environment
- Skilled teaching
  - core concepts and skills,
  - culturally and linguistically sensitive interactions,
  - active and equitable engagement,
  - attention to disciplinary language and reasoning,
  - careful diagnosis and response to students difficulties
- Educational infrastructure

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2. Encourage research in education



- Studies that probe the *insides*
- The dynamic of "instruction", or policy implementation; "inside the black box"
- This is the part that is often invisible and overlooked
- Often more work is done on the corners and edges and contexts — research that **informs** education

Ball & Forzani, *Educational Researcher*, 2007

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Example: Research on children's scientific misconceptions (1980s-)

1. Important scientific theory and explanation about phenomena in the everyday world
2. Young people develop ideas through experience
3. These ideas turn out to be resistant to simple "correction" or telling (important discovery)
4. Can instruction help?

(Work done by Anderson, Smith, Roth; Driver and others at the University of Leeds, Hewson, Minstrell)

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First, scientific knowledge: Plants make their own food

- Green plants are the only living things which can make their own food.
- This process is called *photosynthesis*.
- Leaves are green in colour because they contain *chlorophyll*, which is used in photosynthesis.

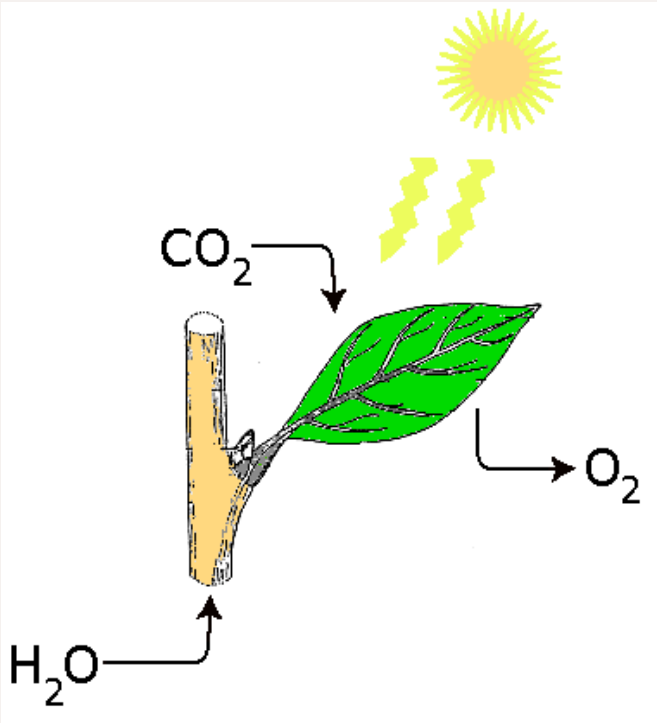


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What does a plant need to make food?

For photosynthesis to take place a plant needs :

- Carbon dioxide from the air
- Light from the sun
- Water from the rain
- Chlorophyll from the leaves



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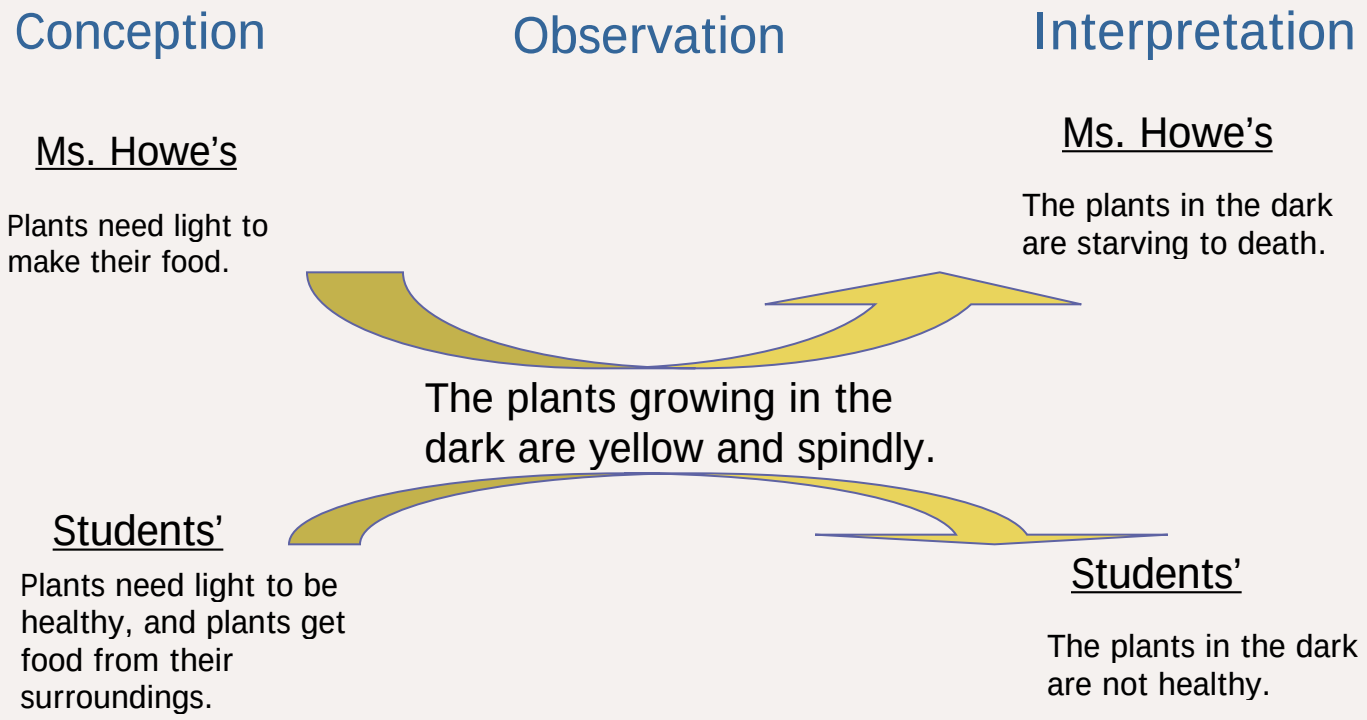
Children's ideas about how plants make food

- Fertilizer is "plant food."
- Plants "eat" plant food and "drink" water.
- Plants get their food from the soil.
- Despite systematic curriculum — experiments with growing seeds and plants both in light and dark, students persisted in believing that plants get food from ingesting materials around them. Light just makes plants "healthier."

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What goes wrong?

- Ms. Howe, 5th grade
- Used SCIS curriculum, well-structured to help students develop understanding of photosynthesis



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Next: Experimental intervention

- Designed experimental text, students were randomly assigned to read typical text material or the experimental text
- Matched in terms of difficulty
- Clinical interviews probed their explanations of how plants get food and their reading strategies

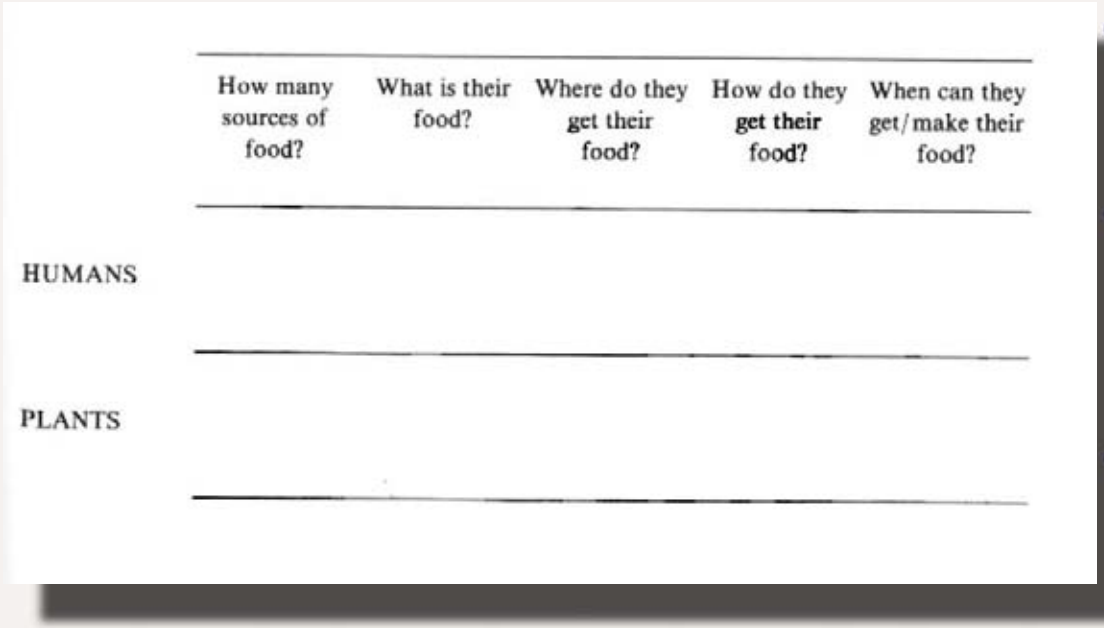
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Design and study of instructional interventions aimed at conceptual change

	# of classrooms per group		% of students understanding goal conceptions	
	Experimental	Control	Commercial materials	Experimental materials
Light and ion (grade 5) 1984, 1986	6	5	18	58
Photosynthesis (grade 5) 1984, 1985	1	1	5	57
Photosynthesis (middle school) 1987	8	5	28	60
Respiration (middle school) 1987	4	9	12	23.5

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Designing explicitly directed tasks and dialogue



	How many sources of food?	What is their food?	Where do they get their food?	How do they get their food?	When can they get/make their food?
HUMANS					
PLANTS					

- Requiring students to confront key ideas and contrasts
- Cues for teachers to ask strategic questions hear and notice what students are saying
- Guidance for noticing what students are (and are not) saying

(Anderson & Roth, 1989)

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Contrasting cases: Research that informs science education

- Studies of 10-year-olds' ability to produce logical explanations
- Research on teachers' beliefs about science
- Studies of attitudes toward science among girls and minority students
- Studies analyzing the content of state curriculum frameworks

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3. Design interventions that . . .

- **Focus on instruction**
- Elaborated with sufficient detail
- Designed for practitioners' learning

Ball & Cohen (2000); Cohen & Ball (2008)

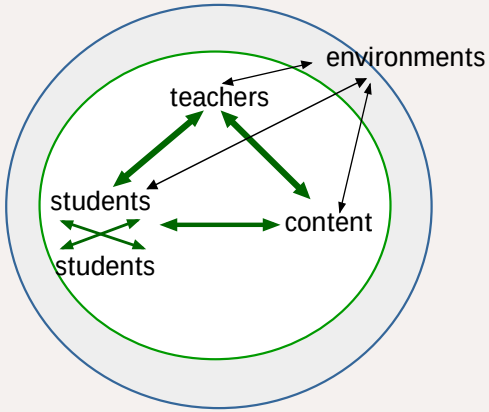
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What would it mean to design interventions that focus on practice?

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Design for a strong instructional system

1. **System**: coordinated, coherent, consistent, principled
2. **Instructional**



3. **Designed**: based on principles of learning, evidence, and made for ongoing adaptation and improvement

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Design for a strong instructional system

1. Build a common curriculum
2. Develop coordinated assessments
3. Build a system of supplying skilled teachers to every school
4. Center teacher licensure (and training) on practice
5. Build schools to support instruction and its continuous improvement

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Common curriculum

1. Develop a common K-12 curriculum consisting of goals, standards, and metrics for their attainment
   - A national or state common curriculum
   - Use of common curriculum material in TE
   - Professional authority and oversight
   - ◆Coherent infrastructure to enable all other elements
   - ◆Evidence that teachers' learning is enhanced when grounded in the pupils' curriculum (Cohen & Hill, 2001; Japanese lesson study)

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Common assessment system

2. Build common assessment systems to track student progress and attainment
   - Build assessments that are coordinated to common curriculum
   - Use new technologies to develop new suites of valid and reliable assessment tools
   - Attend to cultural and linguistic equity
   - ◆Evidence of new approaches to assessment (e.g. progress variables [Wilson, et al.]
   - ◆New tools and psychometric capacity

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System for supplying professionally skilled teaching

3. Build a system to supply skilled teachers with the knowledge and skills to do the work for every school in this country, coordinated to the curriculum and assessment system
    - Shared concept of "safe to practice"
    - High-leverage initial training, licensed by performance
    - Encourage multiple pathways, but meeting common performance standards
    - Continued professional education to develop to higher levels of skilled performance

- Evidence that teachers leave teaching because they cannot be effective (Ingersoll studies)
- Evidence that current teacher training (in higher education or in alternative routes) has weak impact on teacher performance (e.g., Mathematica study, 2009)

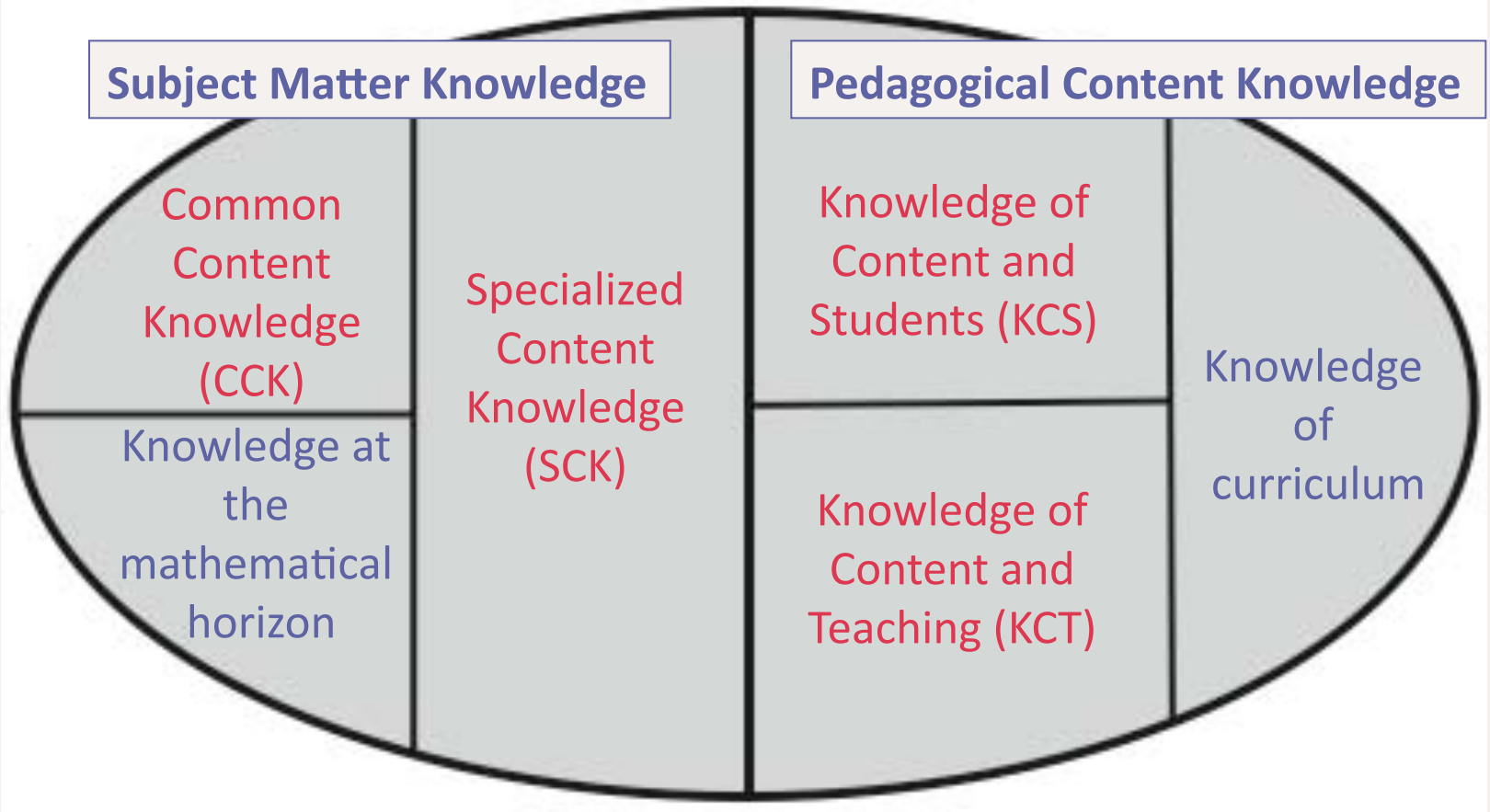
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Teacher preparation focused on practice

4. Focus teacher licensure and training on practice
   - Content knowledge for teaching (Ball, Hill, & Bass, 2005)
   - Decomposition and close modeling, training, and coaching on highest leverage practices (Ball, Sleep, Boerst, & Bass, 2009; Grossman & McDonald, 2008; Grossman, Compton, Igra, Ronfeldt, & Shahan, 2009; Lampert & Graziani, 2009)
   - ◆ Evidence that there is professional knowledge of content and that it can be taught (Hill & Ball, 2004); teaching practice can be taught and scaffolded; addresses the unpredictability of learning from experience and the scale problem

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Mathematical knowledge for teaching



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Schools that focus on practice and its improvement

5. Support improvement in the practice of teaching
   - School organization and professional day ("load") for teachers
   - Mentoring programs
   - Differentiated staffing for beginning teachers, more collective responsibility (like nursing)
   - Continued installments of more advanced practice

   ◆ Early career support is assumed in other occupations and professions (hairdressing, retail sales, service, architecture, nursing, medicine, social work)

   ◆ Similarly, other workplace environments differentiate assignments and support for people at different stages of development

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Making change work

- We've been here many times before (e.g., the "new math," back to basics, A Nation at Risk, the Glenn Commission report, A Gathering Storm).
- We keep gravitating to the same strategies.
- Let's avoid having the same conversation 10 years from now. We know enough to start building the educational system our society needs.

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Thank you!

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