A Modeling Approach to Science Teaching

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As adapted from a
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A Private Universe

- We go through life collecting memories, and organizing them into mental models, or schema.
- Our memory depends on connections; new inputs which do not fit in an existing schema tend to be "forgotten."
- It takes a very discrepant phenomenon to motivate a change in how we make sense of the world.

Algorithms vs Understanding

What use is it if a student can perform the operation shown here:

If they cannot figure out this problem:

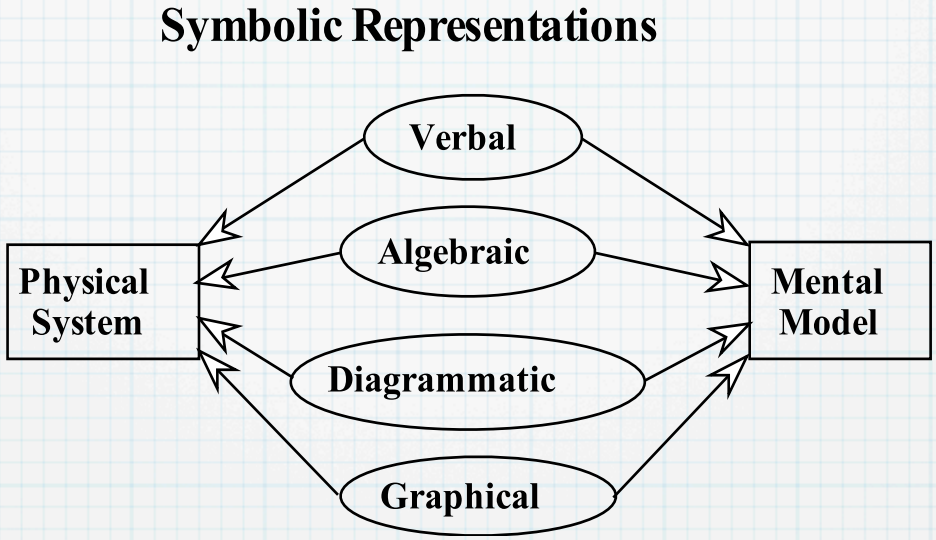
A twelve kilogram piece of wood is cut into six equal massed pieces. What is the mass of each piece?

Students can be taught to perform an algorithm, but it is meaningless without the understanding of what they are doing with it!

Science and Modeling

- Scientists construct and use shared models to describe, explain, predict and control physical sytems.
- By making this process explicit, we help students to:
  - Revise their mental model in the light of experimental evidence and collaborative discourse
  - Understand the scientific process

What Do We Mean by Model?



- Essential and non-essential elements of a physical system or process are identified
- Models are used to represent the structure underlying the essential elements
- In short,a model is a representation of structure in a physical system or process; it is distributed over several representations

Why Models?

- Models are basic units of knowledge
  - A few basic models are used again and again with only minor modifications.
- Students DO work from mental models – the question is which model it will be:
  - A shared, rigorous model with explicit experimental support?
  - An inconsistently applied, private model based on miscellaneous experiences.

What About Problem Solving?

- The problem with problem-solving
  - Students come to see problems and their answers as the units of knowledge.
  - Students fail to see common elements in novel problems.
  - "But we never did a problem like this!"
- Models as basic units of knowledge
  - A few basic models are used again and again with only minor modifications.
  - Students identify or create a model and make inferences from the model to produce a solution.

What Doesn't Work

- Presentation of facts and skills, with the assumption that students will see the underlying structure in the content:
  - They systematically miss the point of what we tell them.
  - They do not have the same "schema" associated with key ideas/words that we have.
  - Students passively listen to teacher.

What Works

- Interactive engagement
- Student discourse & articulation
- Cognitive scaffolding
- Multiple representational tools
- Consensus-based model building
- Explicit hierarchal organization of ideas and concepts into models

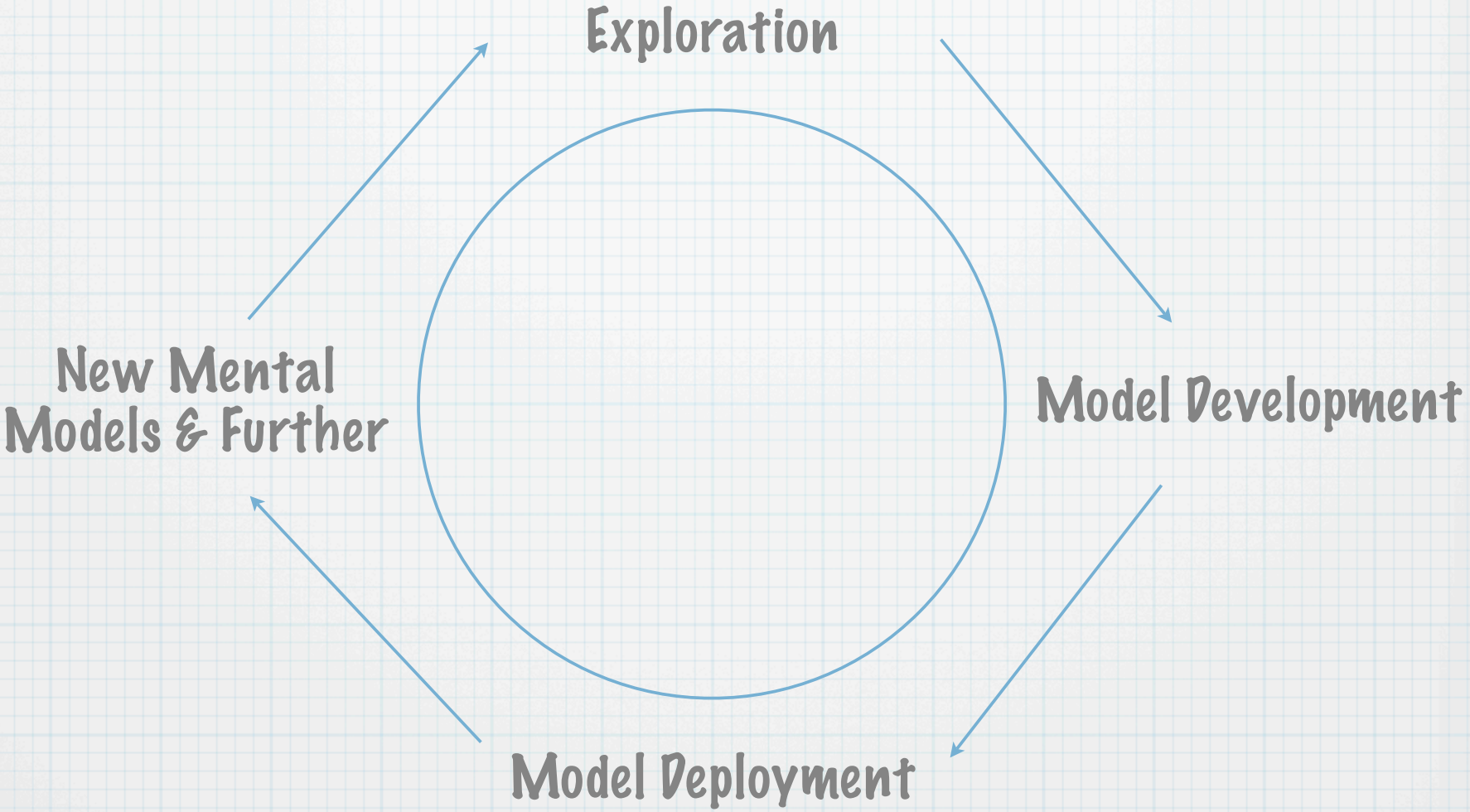
The Modeling Method

- Construct and use scientific models to describe, to explain, to predict and to control physical phenomena.
- Model physical objects and processes using diagrammatic, graphical and algebraic representations.
- Recognize a small set of models as the content core.
- Evaluate scientific models through comparison with empirical data.
- View modeling as the procedural core of scientific knowledge

How is Modeling Different?

MODELINING	vs	TRADITIONAL
constructivist	vs	transmissionist
cooperative inquiry	vs	lecture/demonstration
student-centered	vs	teacher-centered
active engagement	vs	passive reception
student activity	vs	teacher demonstration
student articulation	vs	teacher presentation
lab-based	vs	textbook-based

The Modeling Cycle

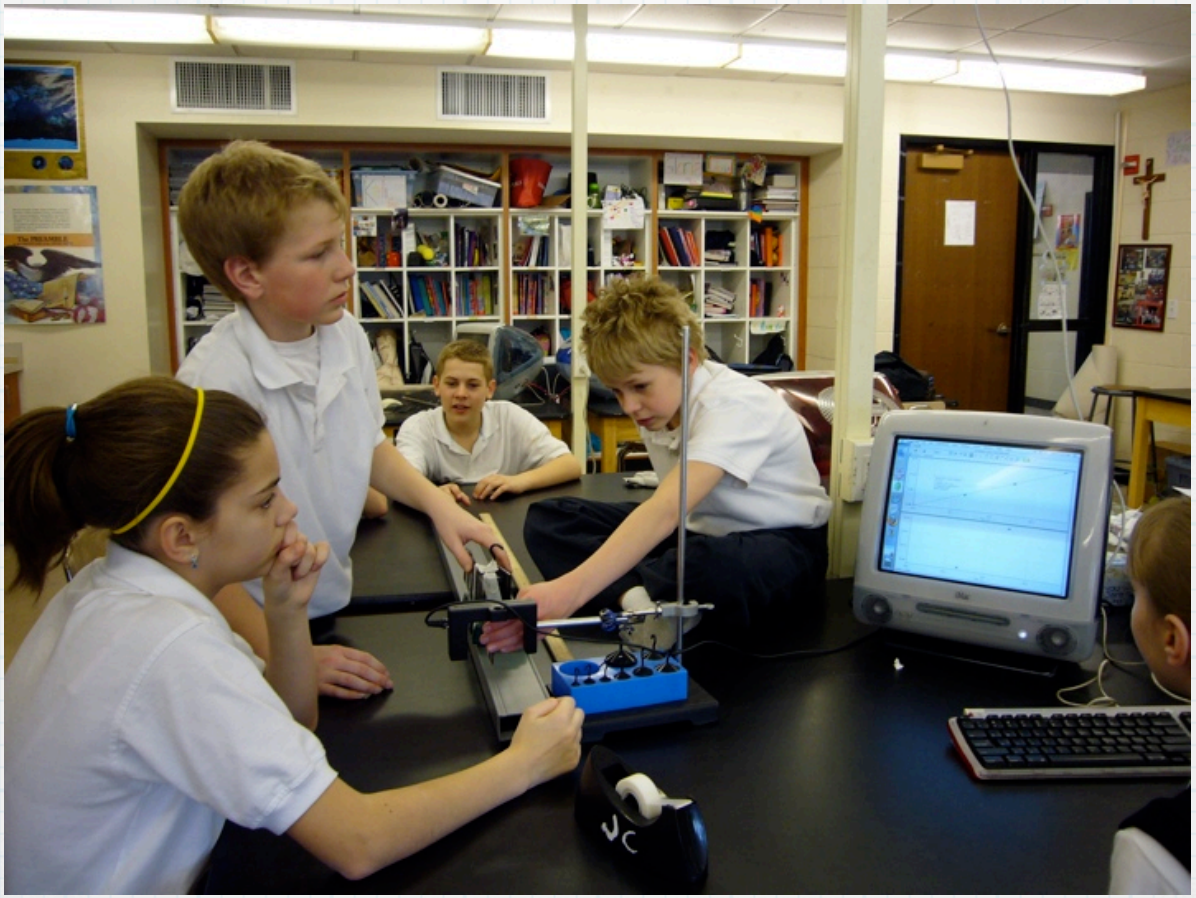


Exploration

- In the exploration stage, the instructor guides the students to design the experiment.
- Oftentimes, students are presented with a discrepant event .
- The model to be developed often uses similar or the same materials as in the exploration.

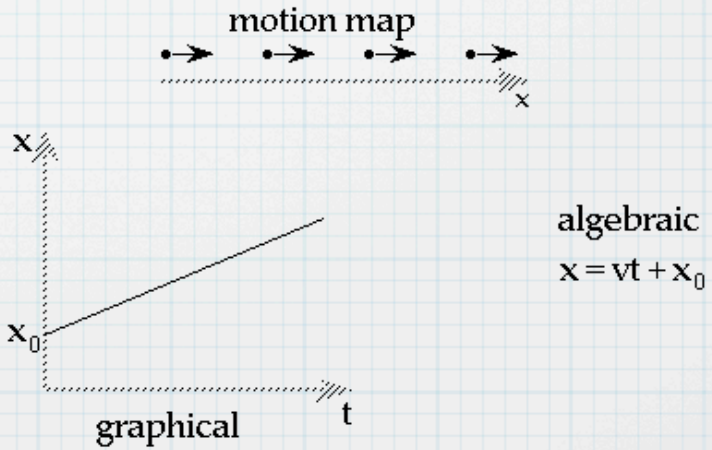
Model Development

- Students in cooperative groups design and perform experiments.



Post-lab analysis

- Students perform graphical analysis of data (linearization, slope and units of slope, area under line & equation).
- Students share their findings via a whiteboard presentation showing:
  - multiple representations, including: diagrams, written descriptions, graphical analysis & equations.
  - justification of conclusions



Students Preparing Whiteboards

* Students use inexpensive equipment to share their representations and analysis.

Students Sharing Their Findings via Whiteboards

* Students share and dialogue about their findings.

Solidifying the Model

- In the post-lab discussion, the instructor helps students to:
  - bring closure to the experiment.
  - flesh out the details of the model, relating common features of various representations.
  - be able to see abstractions of the model from the context in which it was developed.

Putting the Model to Use

- In deployment activities, students learn to apply the model to variety of related situations by:
  - identifying the system's composition
  - accurately representing its structure
- Next, students articulate their understanding in oral presentations, which are are guided by the instructor's and other student's questions:
  - Why did you do that?
  - How do you know that?

Modeling in a Nutshell

- Through carefully guided discourse, students construct models, using various representations, to describe shared experiences with physical systems and processes.
  - Let the students do the talking
  - Ask, "How do you know that?"
  - Require diagrams and representations whenever possible

Modeling Physics

The Modeling approach to teaching physics is broken down into two basic types:

1. Physics for Freshman (Physics First)

2. Junior / Senior level physics (Traditional)

Physics First Curriculum

- Mechanics, non - trigonometric
  - Constant motion particle
  - Accelerated motion particle
  - Particle with no net force
  - Particle with a constant net force
  - Energy (including work & power)
- Waves

Upper Level Physics

* 1st semester mechanics:
* Constant motion particle
* Accelerated motion particle
* Particle with no net force
* Particle with a constant net force
* Particle in motion in two dimensions
* Energy
* Central-force particle model
* Impulsive-force particle model

Second Semester Physics

- Light: particle, wave and photon models
- Waves: oscillating particle, 1-D mechanical waves, sound waves, 2-D mechanical waves
- Electricity (2 approaches):
  - CASTLE: Closed loop model, Fluid model, Resistance to charge flow model, Compressible fluid model
  - E+M: Charge interactions, Electric potential, Circuits, Magnetism

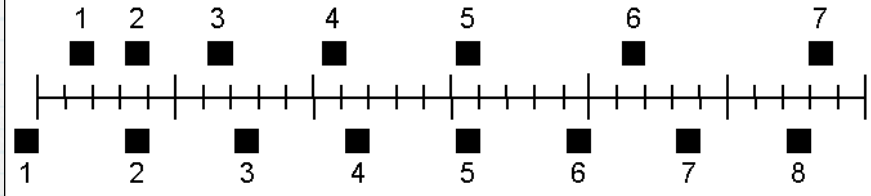
Testing the Effectiveness of Modeling

* The Modeling method of physics instruction was developed in response to low student scores on the Mechanics Diagnostic Test (the precursor to the FCI).

* The Force Concept Inventory was designed by Ibrahim Halloun and is a test of Newtonian thinking.

* It contains distractor answers that are representative of student pre-conceptions.

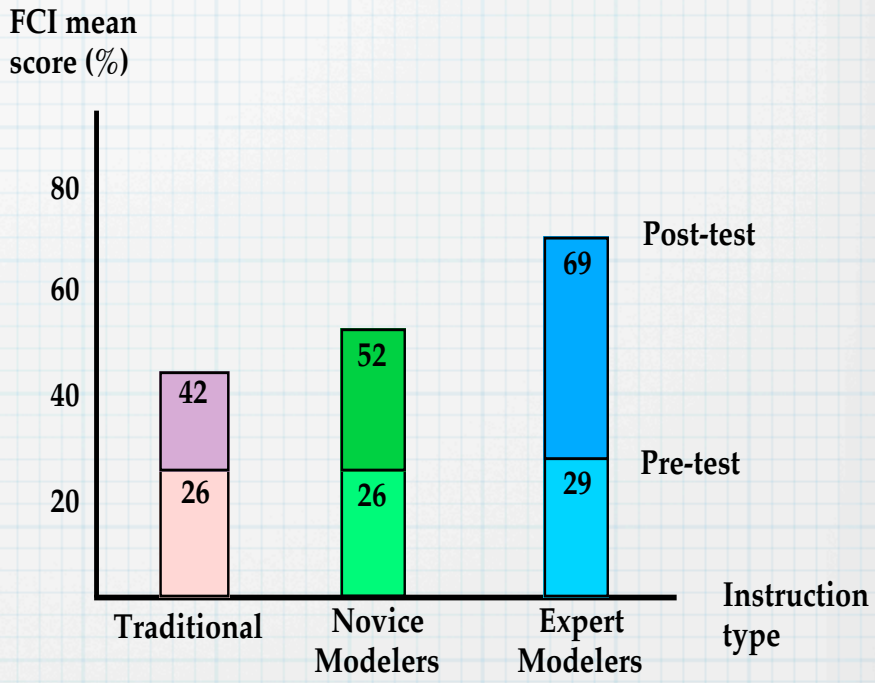
The positions of two blocks at successive 0.20 second time intervals are represented by the numbered squares in the diagram below. The blocks are moving toward the right.



20. Do the blocks ever have the same speed?
(A) No.
(B) Yes, at instant 2.
(C) Yes, at instant 5.
(D) Yes, at instants 2 and 5.
(E) Yes, at some time during interval 3 to 4.

The Modeling Method is Widely Used Because it is Effective

- The data at right are from 7500 high school physics students involved in the Modeling Workshop Project.
- Novice modelers do better than traditional.
- Expert modelers more than doubled their student scores!



FCI mean scores under different instruction types

(Hestenes, et. al)

Where is Modeling Headed?

* Modeling Chemistry is nearly finalized, it looks to be as ground-breaking as physics.
* Modeling Physical Science is available too.
* Modeling Earth Science is ready in draft form.
* Modeling Physics First is available, but still in draft mode.
* Mathematics modeling curriculum soon.
* Modeling can be used in any subject!

Recap: What works

- Interactive engagement
- Student discourse & articulation
- Cognitive scaffolding
- Multiple representational tools
- Consensus-based model building

For More Information

- Classes are held every summer at ASU.
- Local workshops are held around the country.
- Elements of the modeling approach can be adapted to any curriculum!
- Web resources:

1. modeling.asu.edu
2. modelingteachers.org
3. slapt.org

Education as a Journey

* Exploration without guidance usually won't lead students anywhere.
* Guidance without exploration might take you somewhere, but students will not know how they got there!
* The modeling method provides a common, educationally proven structure for all our interactions with the world.

Citations

* This presentation was modified from the publicly available presentation on the ASU modeling web site:
  1. Dukerich, L., models-ing.ppt http://modeling.asu.edu/presentations/presentations.html February 21, 2008. ASU.
* Data on the FCI was taken from:
  2. Wells M., Hestenes D., Swackhammer G., A Modeling Method for high school physics instruction. American Journal of Physics. 63 (7), July 1995, 606-619.