Strategies for Leading Classroom Discussions Aimed at Core Ideas and Scientific Modeling Practices *

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Expert Model Construction Strategies

Expert Study Abstract: NGSS has emphasized modeling practices as essential in science learning, but we need more detailed descriptions of those modeling practices and strategies for fostering them. The left hand side of this poster identifies detailed modeling practices used by scientifically trained experts in think-aloud case studies. The right hand side describes how most of these practices can also be seen in middle school classroom discussions led by experienced modeling teachers.

In the book *Creative Model Construction in Scientists and Students: The Role of Imagery, Analogy, and Mental Simulation* (Clement, 2008), a theory of expert practices for constructing imageable models, is described at four levels shown in Fig. 6: (1) the perceptual (and often motor) processing that makes imagistic mental simulations possible; (2) nonformal reasoning operations such as analogies and thought experiments that utilize imagistic simulations; (3) cycles of model generation, evaluation, and modification; and (4) a control process that decides when models should compete, or evolve. Also see Classroom Study Abstract on right hand side.

Method

- Data comes from video taped case studies, and includes imagery reports and gestures. Subjects were professors and advanced graduate students in scientific fields.
- Transcripts provide finer level of detail than data used in historical studies of scientific thinking.
- Subjects thought aloud about the following problem:

Spring Problem:

A weight is hung on a spring (shown in Figure 1). The original spring is replaced with a spring made of the same kind of wire, with the same number of coils, but with coils that are twice as wide in diameter. Will the spring stretch from its natural length more, less, or the same amount under the same weight? (Assume the mass of the spring is negligible.) Why do you think so?

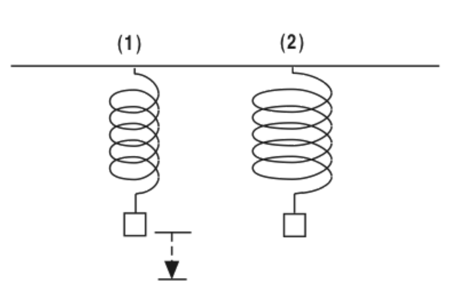

Fig. 1 Original Problem: Which Stretches More?

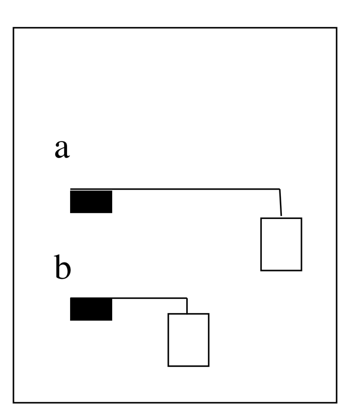

Fig. 2 Expert Analogy Predicting Wider Spring Stretches More

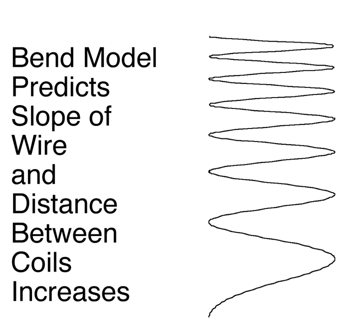

Fig. 3 Conflict Generated by Running Bend Model in Spring Giving False Prediction

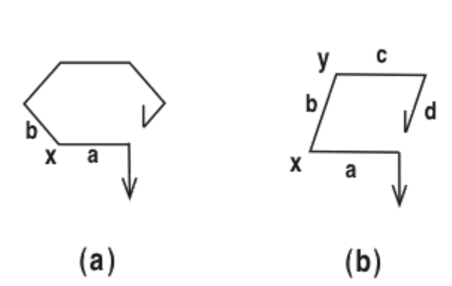

Fig. 4 Cases Leading to Key Insight that Twisting and Torsion are Present in Side (b) and Others

Fig. 5 One Type of Imagery Indicator: Twist Gestures Generated by Subject Thinking about Twisting Side b in Fig. 4b at Different Lengths, Including Extreme Case for Imagery Enhancement

Analysis Example

The sequence of ideas shown in Figs. 1 to 4 illustrates expert learning practices at four levels shown in Figure 6. At Level 2, an **Analogy** to bending rods helps generate a Model of bending in the spring wire, and **Evaluating that Model by Running It** leads to a conflict in Fig. 3, since real springs stretch symmetrically. This leads to modified models in Fig 4, which are themselves evaluated. Staring at 4a, the subject **Runs a Model and Perceives a New Attribute** of twisting and torsion in Side b of the hexagonal coil. After generating 4b, he **Adds Model Elements** in the form of a causal chain: downward force causes twisting, and torsion causes stretching. Thus, he **Generates, Evaluates, and Modifies Models** in the cycle shown at Level 3 in Fig 6. Level 4 contains decisions involving alternative modes including **Model Competition**, such as deciding between bending or twisting models in the spring. Level 1 shows the process of **Imagistic Simulation** hypothesized to underlie much of the reasoning above it. Figure 5 shows spontaneous depictive gestures that serve as one of several kinds of evidence for the use of imagistic simulation. Here the subject imagines that a longer rod would be easier to twist than a shorter rod (Side b in figure 4b), implying that the wider spring would stretch more. The Level 2 strategies bolded above and shown in the diagram below are only some of the Level 2 strategies that have been documented in protocols.

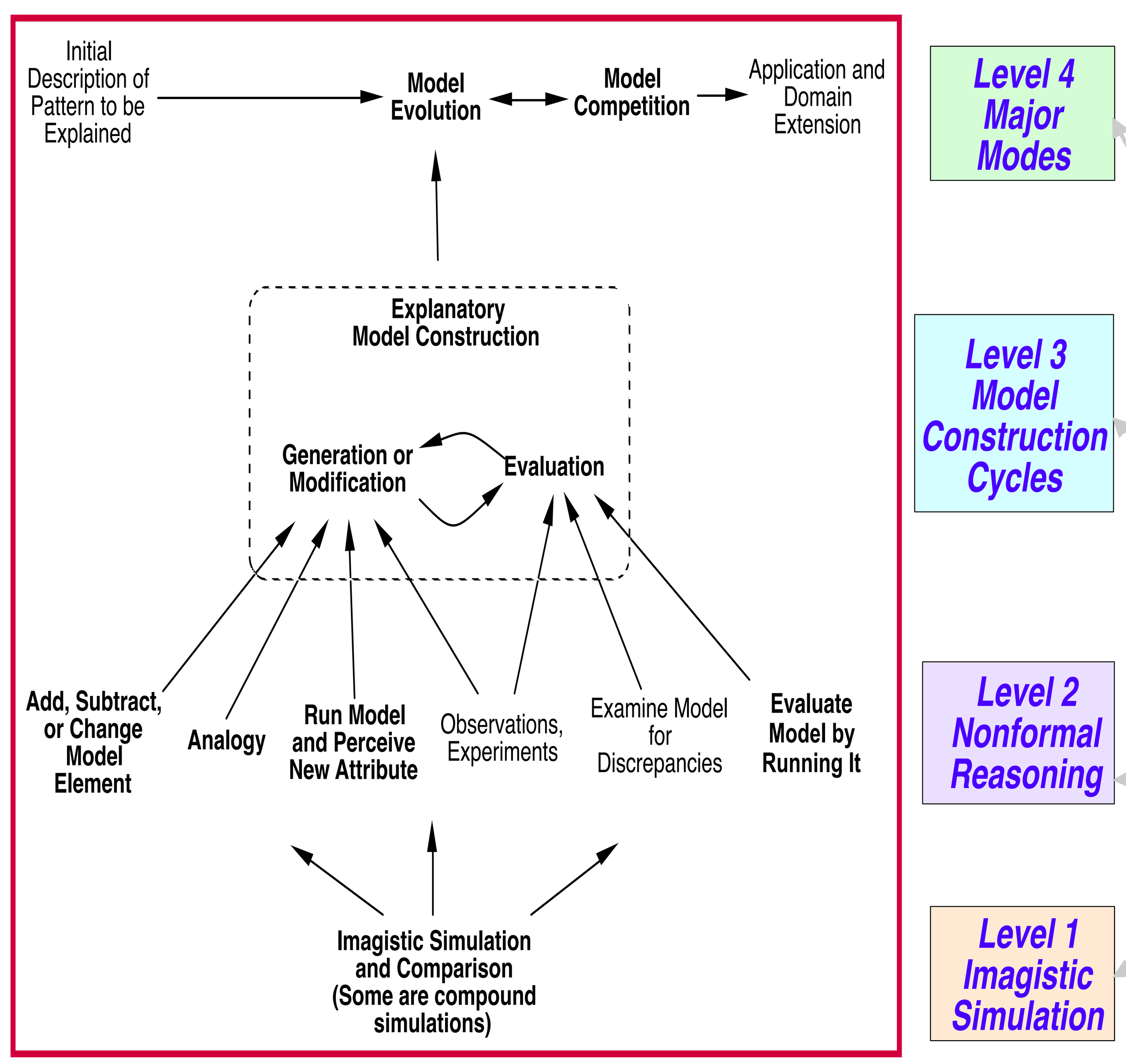

Fig. 6 Four Nested Levels of Practices in Scientific Modeling
Vertical arrows mean 'supports'

Conclusions on Experts

- Many Scientific Modeling Practices Identified at Four Levels
- Levels Help Organize a Coherent Theory of Modeling Practices
- Model Generation, Evaluation, & Modification (GEM) Cycles were Central
- Imagistic Mental Simulation is a Practice Underlying Most Other Practices During Constructive Qualitative Modeling

Extensions. Additional case studies supporting this imagistic simulation framework for understanding thought experiments and analogies in more sophisticated qualitative and mathematical theories of the spring, and for other problems and subjects, are analyzed in Clement (2008, 2009).

Clement, J., (2008). ***Creative model construction in scientists and students: The role of imagery, analogy, and mental simulation.*** **Dordrecht: Springer.**

Clement, J. (2009). The role of imagistic simulation in scientific thought experiments. *TOPICS in Cognitive Science*, 1: 686–710.
http://onlinelibrary.wiley.com/doi/10.1111/j.1756-8765.2009.01031.x/epdf

Teaching Strategies for Constructing Models

Classroom Study Abstract: The pictures in Fig. 7 below show a sequence of circulation models generated and drawn in front of a middle-school class during a whole-class discussion. Surprisingly, many of the expert practices identified in Fig. 6 can be seen as occurring in such discussions led by experienced model based teachers. The four colored bands L1-L4 below identify a large number discussion leading strategies used by the teacher to support these modeling practices. Two central groups of strategies are the teacher: supporting GEM cycles of model Generation, Evaluation, And Modification (level L3 in blue); and supporting the underlying imagery and mental simulations used to run models dynamically (level L1 in tan). Organizing the large number of discussion leading strategies into four time scale levels helps organize the strategies into a coherent theory of modeling instruction.

The four colored rows below show four levels of strategies underlying the teacher's statements and inferred from the transcript and videotape at different time-scale levels. At the highest level, Level L4, are discussion "modes," which can last for substantial parts of a lesson(s) and are often planned ahead of time by the teacher or suggested by a model-based curriculum. Level L3 strategies include teacher strategies to support model generation, evaluation, and modification. Smaller moves at Level L2 support modeling via nonformal reasoning. At the lowest level are quick moves to support student use of imagery as they mentally animate explanatory models and work with them. These match the expert strategy levels in the four rows in Fig. 6. Analyzing parallel strategy levels allows one to show how each level contributes coherently to the one above it, i.e. to its larger purpose.

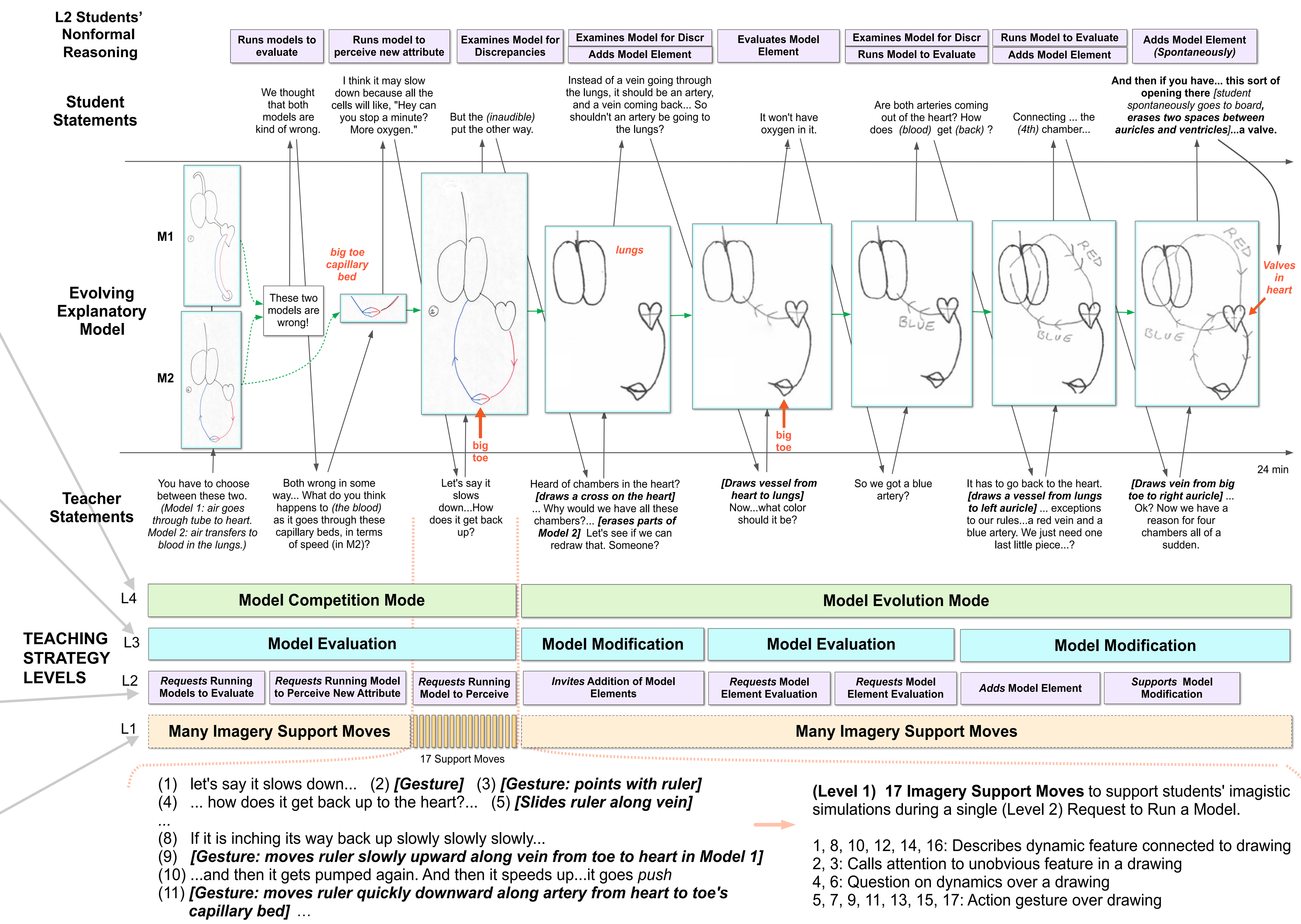

Fig. 7 Teacher-Student Co-Construction and Model Evolution During Whole Class Discussion

Level L1 above represents our newest effort to identify strategies teachers use to promote imagistic communication and mental simulations in classrooms in order to complement verbal communication. The bottom of Fig. 7 shows some of the 17 imagery support strategies coded for a small segment of transcript, including gestures, generating drawings, projecting movements into drawings, and imagery requests from the teacher.

Practices at Levels 1 through 4 can also be inferred for students (only Level 2 is shown here above student statements). Modeling is a complex process, and the analysis of expert protocols is providing us with concepts and vocabulary to describe student modeling practices and teaching strategies. Describing the strategies as occurring at four time scale levels organizes them into manageable sets that can be learned separately.

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Conclusions

- We Need More Detailed Descriptions Of Modeling Practices than in NGSS. Studies of Science Experts can Help Provide These
- Most Expert Practices can also be Seen in Middle School Classroom Discussions Led by Experienced Modeling Teachers
- Four Time Scale Levels Help Organize the Large Number of Discussion Leading Strategies that can Support these Practices
- Two Central Teaching Strategies are Supporting Cycles of Model Generation, Evaluation, and Revision, and Supporting the Underlying Imagery and Mental Simulations Used to Run Models Dynamically
- Imagery Support Strategies Include Gestures, Drawings, and Imagery Requests

Papers are available on CADRE under John Clement, Strategies... or on the website in the upper right.

Images of models in classroom discussion and preliminary analysis by Dr. Maria Nunez-Oviedo.