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 these might be transferred to K-12 classrooms. A case study is described in which a graduate student, working with an experienced science teacher, used the teacher's transcripts and in-class room videos to analyze classroom thinking and instruction.

Method
- Data comes from video taped case studies, includes interviews, and includes peer and self evaluations.
- Transcripts provide finer level of detail than data used in earlier studies.
- Transcripts, in turn, are analyzed using a bottom-up approach.
- The analysis process is described in the poster.

Spring Problem: A wagon is hanging in the spring (shown in Fig. 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

Analysis Example
- The sequence of ideas shown in Figs. 1 to 4 illustrates an expert learner's thinking at four levels shown in Fig. 6. At Level 4, 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 new springs stretch symmetrically. This leads to modified models in Fig. 4, which are then evaluated. Staring at Fig. 4, the subject Runs a Model and Perceives a New Attribute of twisting and torsion in Side b of the helical column. After generating 4b, the Teacher-Student Co-Construction and Model Evolution During Whole Class Discussion

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

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, for other problems and subjects, are analyzed in Clement (2008, 2009).

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 requests from the teacher (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 model instruction.

Fig. 6: Four Nested Levels of Practices in Scientific Modeling

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.