

Modeling Cycle

Modeling Instruction attempts to enhance student achievement through a process called the Modeling Cycle, following Robert Karplus's fine example, the Learning Cycle. Throughout the Modeling Cycle we rely on student engagement and explanation as the dynamic of learning. There are two major parts to the Modeling Cycle, model development and model deployment.

I. Model development

Every unit in our curriculum begins with a paradigm experiment. These experiments must span the desired dimensions of our curriculum. We intend for their interpretations of experimental data to serve as the epistemological foundation and context for all that our students do.

Here is how we approach the paradigm experiments and their analyses.

A. Qualitative description. Students see a phenomenon which is to be modeled, and they suggest relevant descriptors for it. The instructor nonjudgmentally records each suggestion.

B. Identification of variables. From among the descriptors suggested, students, subtly guided by the instructor, then identify those which may have a cause and effect relationship and that can be measured.

Here students determine the components of the resulting model. Irrelevant details are filtered out.

C. Planning for the experiment. Once the purpose is clarified, the instructor presents to the students the apparatus that is available to them. No instructions are given except for the safety of the students or the equipment. We believe that students will only understand their experiment if they themselves create their procedure. The class breaks up into groups of three in order to plan their experiments.

D. Laboratory experiment. Student groups make their measurements using the available apparatus according to their understanding or lack of it. As the semester progresses, increasing use is made of MBL techniques. The instructor may encourage confused groups to use others as resources. Failure is allowed, as is the opportunity to repeat the experiment as needed.

E. Analysis of experiment. Upon completion of their experimental plans each lab group analyzes its data, often using microcomputers, and creates models of the phenomenon. A summary of their experiment and analysis is written on a small whiteboard (24 inches by 32 inches).

F. Presentation of experimental results. Selected groups are called upon to present their findings to the rest of the class. Each group is expected to give a full account about what has been done and express the relationships between the relevant variables in multiple ways (verbal, graphical and algebraic). The instructor questions the presenters as needed to elicit full explanations and to probe for any inconsistencies which have a bearing on their claims. Peer questioning is also encouraged and often is very fruitful. A coherent defense of the group's representations is the goal. The presentation is graded, and this grade is given to each member of the presenter's group. Therefore, the group has a stake in assuring that every member has a thorough understanding of the experiment.

Contradictory results among the laboratory groups are resolved by argumentation and discussion guided by the instructor. Groups who discover that they have made experimental blunders may return to the laboratory on their own time.

G. Generalization. It is often useful to generalize the particular relationships discerned by the students into theoretical statements. For example, after consensus has been attained among the students that the acceleration of a laboratory cart is directly proportional to the force that was applied to it and inversely proportional to its mass, a generalization to Newton's Second Law can be made. The instructor helps the students extract the structure and behavior of the relevant model from the details of the just-completed experiment, and to recognize that this model can be extended to a broader set of phenomena.

II. Model deployment

A. Extrapolation and reinforcement. Carefully selected and designed problems and activities allow students to determine how to deploy their models in a variety of contexts. Also, they allow students to confront common difficulties in the context of their experimental results.

Students work on these tasks in cooperative groups solving all the problems. From each group one person is then selected by the instructor to present the solution to a given problem to the rest of the class. Presenters must explicitly articulate their solutions in terms of models developed according to theory based on interpretations of experiments. During the presentation, if questions arise that the selected presenter cannot answer, other members of the group may offer assistance. Too great a reliance on one's partners, however, may result in a reduction of the group recitation grade.

These class discussions are exceedingly valuable. Student are highly motivated to resolve their difficulties during the preparation of their solutions on the whiteboards, so as to make competent presentations to their peers. They become more articulate in presenting and defending their points of view. When misconceptions arise, they can be addressed in

the context of our models. Students are encouraged to challenge the presenters, and to suggest alternative solutions to the problem. In this approach, the instructor assumes the role of "physics coach", guiding the students by asking probing questions to keep the dialog moving in a profitable direction.

B. Refinement and integration. Lecture demonstrations and counterexamples help the student refine the model, becoming aware of its limitations. Reading assignments from textbooks, film or video clips, aid in the integration of the model into its respective theory, bringing the cycle to closure. Student understanding developed earlier in the cycle provides an experiential and cognitive context which permits more meaningful use of these resources.