"What Behaviors Are Desirable in Students Creating System Models? A Step Before Assessment"

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Assessment is a major concern currently in the K-12 systems community. If parents and other teachers are to be encouraged to accept this new paradigm for problem solving and analysis then some method for measuring the improved thinking skills of students must be demonstrated. How to accomplish this assessment using traditional tools has proven to be elusive, to this point. This presentation attempts to take one step back from the assessment issue and determine what we feel are desirable traits in a student or student group that has chosen to study problems from a systems perspective. The analysis will be broken into three categories: creating models in a modeling course, transferability to other classrooms/disciplines, indication of improved understanding of concepts presented in other classrooms/disciplines. In a modeling course attention will be given to skills involving determining reference behavior, model design, model validation, and model explanation. For transferability the topics will include a focus on model structure and what lends itself to transferability. For improved understanding, some student behaviors that demonstrate a student has surpassed typical conversations will be suggested.

Desired Behaviors of a Systems Modeling Student

<u>Year 1</u>

Early in the student instruction most effort is exerted just trying to teach students how to create readable, simple diagrams (with attention to dimensional consistency) and present information in a graph or table that is relevant, readable, and displays key points of interest. There is also emphasis on communication so helping students learn to write explanations that highlight the important information in complete and fluid paragraphs requires significant time and energy.

1. Uses software well enough to create diagram, table, graphs.
2. Can design models to replicate 3 generic structures: linear, exponential, convergent
3. Can design a simple model that is easy to read: good design, no crossed lines, appropriate # flows, simple to glean major components, names of icons are meaningful.
4. Can create graphs that tell a good quick visual story: choice of graphs to display, choice of scale, units.
5. Can identify appropriate units for every equation.
6. Can explain design of model, dependencies, choice of stock, flow, converters.

After achieving a certain level of competency in the mechanics of model construction emphasis shifts to the beginning concepts of systems modeling.

7. Can explain, using a graph, how flows determine change of behavior in a stock.
8. Can trace and explain simple +/- feedback.
9. Can transfer simple structures across topics.
10. Can use basic commands: step, pulse, if-then-else appropriately
11. Can choose Euler vs Runge-Kutta appropriately. Can choose DT size appropriately.
12. Can explain what a system is.

The next step is to have students begin to extend their learning/application of SD outside the teacher-make SD lessons.

13. Can select an appropriate topic to model.
14. Can gather, interpret, translate data to use in a model.
15. Can communicate in a businesslike manner on the phone or with email with a consultant or organization to gain more information about modeling topic.
16. Uses a model to test policies.

<u>Year 2</u>

Students build modeling skill and expand their reach outside the SD classroom.

1. Can explain more complicated +/- feedback.
2. Can build models of 3 generic infrastructures: s-shaped, oscillation, overshoot & collapse.
3. Can identify system scenarios in newspaper and magazines.
4. Can create simple model structures of different system scenarios from newspapers and magazines and explain the structures.
5. Can identify leverage points in a model.
6. Can explain transfer of loop dominance.
7. Can use multipliers appropriately.
8. Understands how delays affect behavior of a system.
9. Can identify system scenarios and generic structures in topics studied in other classes.
10. Can explain an appropriate systems relationship to a teacher/student in another class.
11. Has an appreciation for the breadth of disciplines to which systems applies.
12. Tests model's robustness.
13. Can differentiate between event reporting and systems/feedback approach reporting.

<u>Year ?</u>

At this point it is hoped that modeling has become a comfortable tool the student will use to understand her/his world.

1. Applies system tools/structures to enhance student's own learning.
2. Uses core structures to help understand/ describe new systems
3. Improves students ability to explain model behavior.
4. Improves students ability to articulate what they learn from the modeling experience.

"Materials for Introducing Systems Modeling in Mathematics, Grades 9-12"

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If a system dynamics modeling paradigm is ever to make its way into the high school classroom in a significant way materials must be available for interested teachers. A set of lessons for use in supplementing a traditional secondary school mathematics curriculum has been developed with emphasis on the study of the behavior of traditional functions over time. The first chapter, for example, is about functions which change at a constant rate. The chapter starts with the use of the motion detector, a sonar device connected to a computer lab interface. Students move in front of the detector in specified patterns as the graphs of the motion are displayed in real time on a projector. The students are to study the connection between the words describing how they were to move and the characteristics of the graph displayed. Different lessons are provided so students in a beginning Algebra course, an advanced Algebra course, or a Pre-Calculus course use similar motion but interpret the motion using increasingly sophisticated vocabulary and with attention to more depth of analysis. From the motion detector, lessons proceed to the study of the theory of finite differences. From the theory of finite differences STELLA model diagrams are constructed for the particular function type and application problems are presented requiring students to build diagrams that will exhibit the appropriate behavior to solve the problem. The problems start simply, matching those that might appear in a traditional math text. However, small extensions are made to some of the problems so they begin to ask the student modify a structure and apply it to a more interesting problem that students would have been able to study at a given level, using an equation interface for quantification. Also, some problems require that structures be combined, once students gain experience with more than one type of structure. Each lesson requires one or two 45 minute class period to complete. Periodically, story projects are included, so students who really enjoy this approach can expand their study. The projects are expected to be completed outside of class and may take one to two weeks, depending upon the time a student can commit to the project. An outline of the lessons is included below. This set of student lessons, teacher answers, and all models on disk is being published by High Performance Systems, the publishers of the STELLA software. A final title for the materials has not been determined.

Introducing System Dynamics Modeling in Algebra, Pre-Calculus and Calculus Classes

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