British Petroleum Is Not Jackson Middle School: Different Best Modeling Practices For Different Environments

Ron Zaraza
CC–SUSTAIN Project
Co–Director
Wilson HS
1151 SW Vermont
Portland OR 97219
(503) 235–2745
rzaraza@pps.k12.or.us

Tim Joy
CC–SUSTAIN Project
Core Team member
La Salle HS
11999 SE Fuller Ave
Milwaukie OR 97222
(503) 659–4155
lasalle4@northwest.com

Scott Guthrie
CC–SUSTAIN Project
Core Team Mmember
Wilson HS
1151 SW Vermont
Portland OR 97219
(503) 916–5280
sguthrie@teleport.com

Educators attempting to bring the concepts of system dynamics into the classroom have always looked to the experiences of systems dynamicists for guidance. Until recently, the only training in system dynamics focused on its traditional policy and business uses, so teachers followed the ideas of the leaders in the field with great faithfulness. The importance and impact that system dynamics pioneers have had in the development of educational uses of systems is evident in the role people such as Jay Forrester and George Richardson have played at the K-12 Systems conferences. Their participation in the K-12 systems in education listserv (k12ed@sysdyn.mit.edu) is further evidence of their interest and commitment to the use of System Dynamics in the K-12 environment. Thus, it is only appropriate that a discussion they were involved in on the list–serve provided the motivation for this paper.

The question of "best", "preferred", or "most probably successful" practice for model construction became the focus of a discussion. This was a result of a question about the possibility of modeling a high school as a system. George Richardson observed that "Since the early days of system dynamics it has generally been agreed that one can not build a model of a system (like a high school), but instead one must take a problem or interrelated set of problems as the focus of the model."[1] He suggested that modeling the system, rather than a well defined problem within the system, would be difficult, if not impossible. This response provoked a series of exchanges lasting about a week, in which some participants asserted that the need to focus on problems, rather than a general system, was unnecessary, while most supported Richardson. An interesting insight came from Jay Forrester, who, while supporting Richardson, noted that changing George's assertion to "it has generally been true"[2] might well resolve the issue, since it is a less absolute statement. The issue, however, was not one that participants were willing to drop.

It quickly became clear that the underlying problem was understanding model conceptualization. What are the necessary (or at least useful or most probably successful) steps or components in conceptualizing and constructing a model? As the discussion developed, Richardson shared the components of model conceptualization he uses with his students:

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[1]George Richardson in a message to the K–12 listserv dated 12/31/97
[2]Jay Forrester in a message to the K-12 listserv dated 12/31/97

- Problem focus*
- Problem Dynamics*
- Context*
- Audience*
- Model Purpose*
- Model Boundaries
  - –temporal
  - –conceptual
  - –causal
- Aggregation
- Reference Modes
- Initial Policy Options
- Model Sectors
- Important processes in each sector
- Important levels and associated rates in each process and sector
- Apparently important feedback loops
- Next steps[3]

The components identified with an asterisk (*) are considered to be the most crucial to the modeling process.

Richardson's components focus attention on a problem, not on a system. Listserv comments from other participants who are actively involved in the modeling of dynamic systems tended to support the emphasis on problem identification and delimitation as primary factors in successful model building. This approach to model conceptualization has also seen wide-spread use in educational applications of system dynamics. It is the ability of system dynamics to address interesting and exciting problems outside the reach of conventional tools and methodology that often first attracts teachers. Among members of the CC–STADUS/CC–SUSTAIN core team most initially saw system dynamics as a better way to teach and solve problems in mathematics, physics, history, biology, and other disciplines. This focus is consistent with the "best" or "common" practice of focusing development of a model on a clearly defined problem. It is also an entirely appropriate use of system dynamics in education.

The educational materials developed at the K–12 level usually follow this approach. The materials are designed to address a clearly defined problem, develop a model to illustrate it, then use the model to obtain actual numerical results. Several curriculum packages available from the Creative Learning Exchange provide excellent examples of this approach to using systems dynamics. The Radioactive Decay package consists of preliminary text and models about linear and exponential growth and decay, simple models and questions about radioactive decay, and finally, exploration of radioactive decay sequences using both a model and questions. The entire curriculum package is defined by focusing on the problem of radioactive decay. Activities develop both the concepts and models, providing an alternative to traditional approaches. The final activity, in which students construct a 3–element radioactive decay sequence, includes a model that yields numerical results which cannot be obtained with the mathematics

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[3]George Richardson in a message to the K–12 listserv dated 1/2/98

normally available to K-12 students. Thus, the models are used to solve increasingly complex variations of the basic problem.

A variety of predator–prey relationships are also examples of the problem–focused use of modeling. Because the interrelationships are impossible to describe quantitatively without very advanced mathematics, they have frequently been subjects of dynamic models used by teachers. They provide the only vehicle which is able to explore the problem of how species interact and yield numerical results. They are also excellent examples of the problem–focused modeling activities that constitute the vast majority of models and curriculum currently in pre–college use.

Since content–specific ideas are an important part of the curriculum in every discipline, the use of system dynamics as a problem solving tool is an appropriate and powerful use. However, it is important to guard against system dynamics remaining only a tool. For system dynamics to have its maximum impact on student learning, it is necessary to look at the real potential of systems concepts. Teachers repeatedly justify the use of models and system dynamics as a way of “getting students to ask better questions”. The specific–problem oriented models do develop this ability to some degree. However, the real power of system dynamics is its potential to equip students with the ability to look at real–world systems and begin to ask questions that will build an in depth understanding of the system.   Learning through system dynamics can develop the critical thinking and analytical skills that will allow students to make intelligent evaluations about the complex problems and systems they will encounter. In order to maximize the possibility for this type of intellectual growth, modeling and systems concepts must not only focus on narrowly defined problems. Much broader and ambiguous problems can and should be used as a starting point, since this is the pattern students encounter in their daily lives.

Models that develop the questioning skills are often not problem–specific, that is, they do not look at a well defined and delimited problems. Instead, they tend to be models painted with a “broader brush”, lacking in well defined boundaries or details. Looking to the “best” practice of system dynamicists, teachers often reject such models because they are not “accurate” enough, because they don’t allow students to draw definite conclusions about clearly defined questions, they don’t give enough “facts”. The models are often described as “ambiguous”. These types of models often trigger criticism of the model and even the idea of modeling.

An experience that a number of Portland (Oregon) area teachers have had illustrates this type of situation. Global studies is a freshman (9th grade) course taught in many local schools. One of the unifying ideas that teachers often use in this class is the role population growth plays in the difficulties experienced by developing nations. To explore this, they use a simple population model with a single stock, *population*, a *births* inflow and a *deaths* outflow. The model produces simple exponential growth. When run for a period of a hundred years, the results are dramatic and frightening. Nations like Malawi show a growth in population of 2200% or more.

Almost inevitably, the students react to the model by talking about the horrible situation that the people will find themselves in. Often the teacher gives them a deceptively simple assignment: develop a policy that can be implemented to prevent disaster. The result is unrealistic, and not satisfying. Policies show little understanding of the system, because the system hasn't been explored. This lack of realism may motivate teachers to step away from the use of models. The problem is not with the model, but with the educational use of the model. Much greater benefits can be gained if the simple model is seen as the "doorway" to the system. Stopping at the door yields little knowledge. Going through it and exploring is riskier, but can yield great benefits. This riskier path is also followed by some teachers.

In most classes, one or more students react negatively to the model results. They say that the situation will not develop as modeled. The criticisms they express vary, but frequently include:

The birth rate won't stay that high. (for a variety of reasons)
The death rate will increase. (for a variety of reasons)
There will be massive starvation
They will add more farmland.
They will practice birth control.
They will emigrate.
They will import food.
They will impose family planning.
They're not that stupid!

These comments can present a teacher with an opportunity to explore the system in greater detail, to step fully through the door. This exploration begins with questions about the comments. What are you assuming? What do you know? What do you think? What other information do you need? Where can you find the information? (Note the similarity to Richardson's components!)

These questions lead to a variety of activities. Students can do individual research about important factors that are revealed by both teacher and student questions. They can explore interconnectedness of the topics and questions. Further modeling is a possibility, either by students, the teacher, or a cooperative effort. Of course, each of these activities can initiate the cycle all over again. The choice is up to the instructor. The result, however, is an appreciation for the inherent complexity of most problems we encounter. Rather than being surrounded by simple cause–effect relationships, students are faced with increasingly complex situations in which small actions can have large reactions. This pattern leads to in depth learning, as well as initial experiences in exploring a system. The understanding of system dynamics grows more dramatically than in problem–focused activities. System dynamics concepts become an implicit part of the syllabus, rather than a tool for learning content.

This approach to using system dynamics is both riskier and more time intensive, but has the potential of greater gain. When the progress of the course is defined by the questions students ask, where the class is going is uncertain. Following the student's interest may increase student involvement, but it can also expand the time spent in a single area. What makes the approach even more difficult is development and selection of suitable "initial" models. There are few examples of such models to get teachers started. Systems suitable for exploration exist, but emphasis has been in the direction of more clearly defined problems. It is clear that major efforts must be made to identify systems and additional questions that lend themselves to this approach before this alternative use of systems can grow beyond a few practitioners. Once the number of such simple models and curriculum materials grows, more teachers can begin to pursue systems–focused model use as well as problem–focused modeling.

Clearly in education there will ultimately be two distinct “best” practices in modeling. One, following the widely accepted practices of traditional systems modeling, focuses on well defined problems, developing models that build a detailed understanding of the problem. The other appears to be almost diametrically opposed. It looks at systems in the broadest sense as an initial step, building understanding of the system over time. There is no well defined problem. The exploration of the interconnectedness among and within systems itself is the “problem” These two different practices reflect the fact that the use of systems in education addresses different needs than in traditional system dynamics. While solving and explaining defined problems is important in both education and traditional uses of system dynamics, education has a larger and more vital task – development of thinking skills. System models that generate more questions than they initially answer may well be the most powerful “tool” for developing this most important of skills. The transition to use of systems concepts in daily life is quick and obvious. Even system dynamics novices find it difficult to watch the evening news or read a newspaper without wondering how businesses/governments/individuals can propose and implement simple solutions to what are obviously problems arising in complex systems. Experiencing that same kind of situation in classes will build that realization in students.

The two “best” modeling practices actually complement each other. Systems–focused models are inherently simple in structure, serving as “triggers” for the questioning process. Their purpose is not to address problems, but rather to expose their presence in a system. Problem–focused models are designed to answer well defined problems. Frequently, the system–focused models allow students to generate more specific problems that can be the focus of models. Even if models are not used, system concepts are focused on the questions and problems revealed by discussion of the systems models. Extensive work is being done in this area by Scott Guthrie and Megs Patton of Wilson High School (Portland, OR) who are teaching a Science-Technology-Society/World issues course using system dynamics. They report remarkable development of insights into complex issues by high school juniors and seniors.

With the realization that the purposes of system dynamics in education are more varied than in traditional system applications, it is possible to wonder whether or not it is possible to define the components of model conceptualization for educational uses as George Richardson has for general systems work. Returning to his components, it is clear that he has already done the task for educators. His components for general systems work are identical in problem–focused educational modeling. Even for those very different system–focused models, his components work quite well. What remains is a matter of definitions or clarifications. Looking at developing systems and thinking skills in students, Richardson’s “problem focus” becomes a broad rather than a specific problem. Exposing and exploring the interconnectedness of a specific system rather than one problem in the system becomes the focus of the model. “Model purpose” becomes an emphasis on raising questions rather than answering them. All other components transfer to the different approach with little significant change. The components of conceptualization truly are generic, with only the context changing. They serve as a useful guide for both “best” practices in education.

References

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2. Richardson, George P. (Editor), Modeling for Management: Simulation in Support of Systems Thinking (International Library of Management). Dartmouth Pub. Co, 1996