A SELF-PACED APPROACH TO TEACHING SYSTEM DYNAMICS

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Abstract

System dynamics is a logical and powerful way to organize one's thinking and to guide one's explorations of the world. It is generally not, however, an intuitive or transparent approach; support in the form of basic instruction, as well as guidance in applying the discipline is required for new users to become proficient and confident. Traditional training approaches in this discipline depend on intense, relatively short-term training, in the form of workshops or courses with varying degrees of follow-up support. After such formal training, support is largely limited to printed manuals and often infrequent consultations. In our experience, such approaches are not fully effective in providing the new system dynamicist with the breadth and depth of skills and insight needed to make further progress once the training is ended.

In response, we have developed and refined a pair of self-paced, computer-driven products to augment and support the more traditional training approaches. A STELLA TUTORIAL is a hypertext product designed 1) to instruct the new modeler in the basic mechanics of constructing simulation models in one of the most widely used educational modeling programs, and 2) to provide an electronic "help" feature in the form of a Glossary. A STELLA TUTORIAL COMPANION is a supplemental product that 1) reinforces the systems thinking and dynamic modeling lessons of the Tutorial, 2) broadens the modeling illustrations and applications beyond the singular focus on human population growth of the Tutorial, 3) demonstrates transferability of basic system and model structures from one discipline to another, and 4) illustrates a number of approaches with which simulation models can be applied to curricular needs.

Together the two products provide self-paced and self-directed instructional and illustrative materials that are extremely effective in a number of uses: 1) as a prelude to more traditional training, 2) as a review and extension of lessons from such traditional settings, 3) as a means to provide system dynamics instruction outside of valuable class time during courses but which are not themselves primarily focused on that discipline, and 4) in admittedly limited cases, as sufficient training vehicles for establishing modeling facility. As such, these products now constitute a fundamental and invaluable tool in our various efforts to train our students and other educators in the productive use of system dynamics.

Introduction

Many efforts over the past eight years to engage educators in intense, short-term (typically three to five day) training sessions to provide both a basic understanding of systems thinking and the essential tools and confidence with which to create dynamic models, indicate that such exposures are ineffective at best and, at worst, counterproductive. Typically, a large fraction of trainees are frustrated, unable to recall enough of the mechanical details nor recognize appropriate applications for their new skills. Others, who do in fact master the mechanical skills, many of whom have strong math and/or computer programming backgrounds, flounder in their efforts to demonstrate to their peers how and where modeling may prove useful. Those who ultimately learn to model and see the broad power of modeling may be the exception to the rule.

Several factors contribute to this failure. The first and most important relates to the speed with which vital information is disseminated and the demands of integrating those skills to build larger and more complex models. Such multiple opportunities to encounter difficulties are likely to produce frustration and failure as challenges and complexities mount. Central to failure and the desire to quit is the fundamental reality that individual "learning curves" vary so dramatically that the achievement and success of any small contingent of participants places extraordinary pressures on all others. Summary evaluations collected from participants point to a reinforcing feedback, where mounting frustration, either in mastering the mechanical skills or in failing to recognize adequate applications within one's personal area of interest, leads to discomfort and disinterest.

In seeking to correct these shortcomings, we have focused on developing and refining a pair of self-paced, computer-driven products to supplement the hurried and competitive dynamic of the workshop with a more supportive environment. These products introduce the basic mechanics for constructing simple simulation models while, equally critically, they 1) challenge the new modeler to recognize the powerful transferability of simple "generic" structures to a multitude of disparate disciplines and circumstances, and 2) provide insight on the ways that models can be constructed and presented to support learning.

A STELLA TUTORIAL

Early in our instructional experiences, we found that a progressive development of a single basic theme, dealing with human population growth, was effective for supporting student learning. In part, this reflects the generalized appeal of the topic and its connections with myriad other subjects including economics, history, environmental affairs, etc. Equally important, the "system" of human population growth readily lends itself to illustrating how and where incremental improvements in model construction skills reinforces both one's desire and one's range of possible modeling opportunities. The logic of using a progressive sequence of increasingly more complex and realistic population models has been rolled over into the self-paced TUTORIAL.

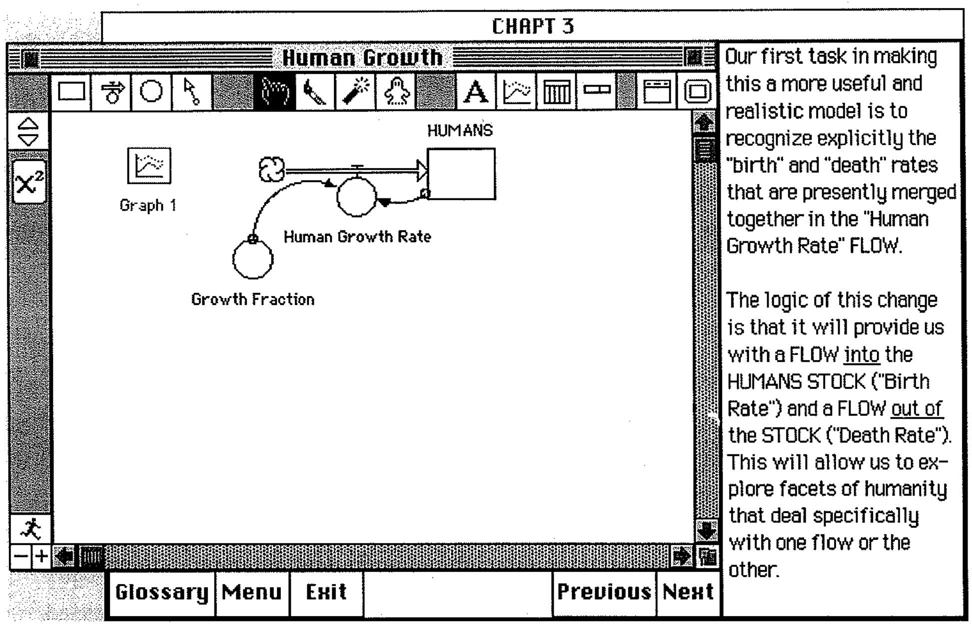

FIGURE 1: Sample screen from A STELLA TUTORIAL.

The primary focus of the Tutorial is on the technical skills needed to build STELLA models. It simultaneously uses HYPERCARD 2 (®Apple Computers Inc.) to provide modeling instruction and STELLA (®High Performance Systems, Inc.) for the actual construction and manipulation of the simulation models (see Figure 1).

The Tutorial contains two major and one minor components. The first major section is the set of eight Lessons that progressively guide the user through a series of increasingly complex and realistic models, building progressively more sophisticated modeling skills in the process. These sequential topics follow the sequence of developments originated in our training workshops:

1. Compound (or exponential) growth (Lessons 1-3; most of the major building blocks and tools are introduced in these initial Lessons)
2. Goal-seeking behavior (Lesson 4)
3. Multicausality (Lesson 5)
4. Use of "soft" converters (Lesson 6)
5. Use of multiple or disaggregated stocks (Lesson 7)
6. Connecting populations to other systems (Lesson 8)

The second major section of the Tutorial is the Glossary. Since we desired that this Tutorial serve as a basic reference tool for more experienced users (as well as a training vehicle for beginning modelers), we designed a reference section, or "electronic user's manual," to provide a convenient source of explanation and support for the major components and features of STELLA. In the Glossary, the user finds graphical and prose explanations and often the opportunity to move to the portion of the Tutorial in which that particular feature was initially explained.

Finally, in response to our students' requests to have the resources of the Tutorial available to them while they were building their own models, we have incorporated a simple unit consisting of a blank, untitled STELLA model, HYPERCARD-linked to the Glossary, and, through the Glossary, to the rest of the Tutorial. Using this component, students engaged in building their own models can refer back to the resources of the Tutorial lesson, if necessary.

A STELLA TUTORIAL COMPANION

The logic for a Tutorial Companion became apparent shortly after initial distribution of the Tutorial. The early Lessons of the Tutorial bolstered people's confidence and ability to master basic mechanical skills; some proceeded to race as quickly as possible through the remaining Lessons of the Tutorial. After completing the Tutorial, people reported being comfortable with the processes for building increasingly complex population models. However, their particular knowledge could not be readily transferred to other dynamic systems. In short, the Tutorial provided the skills to build models, but little insight on what to model or what to do with the model once it was completed.

What was necessary, we were advised, was a supplement permitting people to "stop" after each Lesson and reflect on what they had learned. Thus, was born the idea of a Companion: a way to maximize one's understanding of "what to" model to supplement the Tutorial's "how to model."

Having originated as a paper supplement providing Tutorial users with an eclectic (as one would expect of an oceanographer and an historian!) selection of "additional" modeling opportunities, the Tutorial Companion has evolved into a NETSCAPE-based product with STELLA models running as needed, designed for flexibility of use, and encompassing a broad range of exercises and resources with which to capture and hold a modeler's attention.

The Companion contains eight Chapters, one for each Lesson in the STELLA Tutorial, and intended for use after completion of that Tutorial Lesson. Each Chapter of the Tutorial Companion has five sections to guide modelers through a logical sequence of steps (Figure 2).

1. "A Review of Mechanical Skills and Concepts Developed in the Tutorial" simply reminds the modeler what they should have learned from the corresponding Tutorial Lesson. Key terms and concepts are highlighted and, where necessary, the Companion opens its own Glossary to provide appropriate definitions and/or brief reviews.
2. "Options for Building Models -- Step-by-Step Instruction." supports the student in building one or more models which employ the same generic structure (generally in an unrelated content area) as the Tutorial's population model. This provides both modeling practice and recognition of the potential breadth of systems that can be modeled with that particular generic structure.

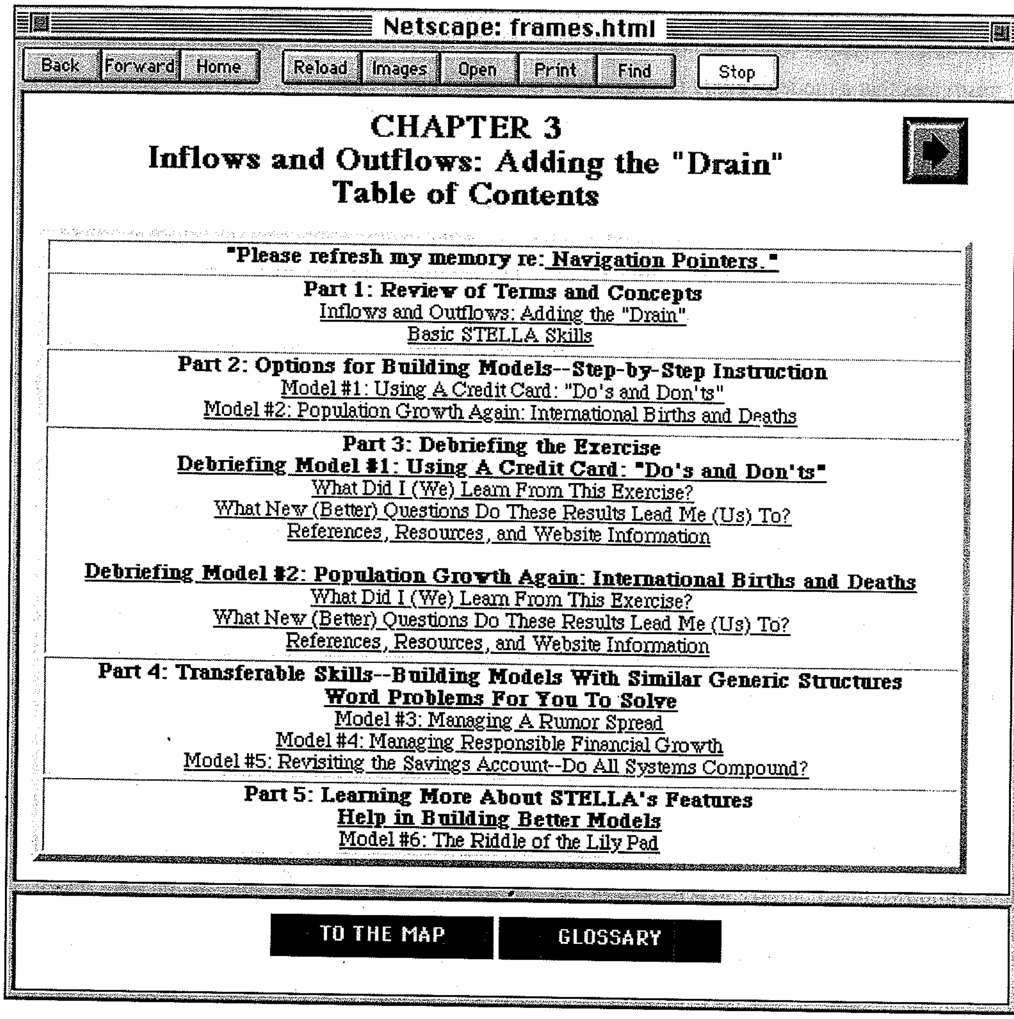

FIGURE 2: Sample Table of Contents Screen for a Chapter of A STELLA Tutorial Companion.

3. "Debriefing the Exercise" is the next section. The actual construction of models should always be followed with thoughtful reflection to appreciate what was learned. This involves two critical questions. The first, "What Did We (I) Learn From This Exercise?" reminds us that an essential element of modeling is to communicate clearly what has been discovered about the system as a consequence of building and running a model. That is followed by the second fundamental question which, ultimately, could (in our opinion, should) be used as a measure of effectiveness for any learning experience: "What New (Better) Questions Do These Results Lead Me (Us) To?"

This, in turn, leads to the final component of the "debriefing" section: "Additional Resources." These represent both the sources of data and relationships we used and additional resources that a modeler could use to modify or expand that model.

4. "Transferable Skills" further advances a theme introduced in Section 2. Recognition that the "workings" of one system can be used to understand other seemingly unrelated systems that share common structures can and must, as Forrester reminds us (e.g. Forrester, 1990), serve as an essential goal for learning about system dynamics. After having supported the construction of one or more models, the Companion now offers additional modeling options to explore.
5. The fifth and final section of each Companion Chapter, variously named, functions as what we call the "stretch" piece of the Companion: It challenges modelers to consider additional features of STELLA that are not necessarily covered in the Tutorial (e.g. arrays, messages, specific Built-in functions) which can and should be used to enhance one's options for building or presenting a model. We ofttimes use an "authoring" front to illustrate how non-modelers could manipulate and see model output without actually being overwhelmed by the model itself. As in all other sections of the Companion, careful instruction is provided to assist the interested modeler in borrowing ideas or making appropriate modifications to tailor the model to her/his own desires.

In addition to these five sections for each chapter of the Companion, the modeler has access, via buttons located at the bottom of each screen, at all times to the Glossary and to the opening "map" which allows one to navigate into any one of the eight Chapters.

Summary

A STELLA TUTORIAL and A STELLA TUTORIAL COMPANION were developed to provide self-paced and self-directed instruction: developing a basic understanding of mechanical model-building skills and vocabulary, and bolstering a broader, more powerful understanding of systems behaviors by providing diverse model-building exercises and supplementary materials. Used in tandem, these tools seek to advance the "learner-directed learning" pedagogy which has been championed by educators and professional system dynamicists alike (e.g. Draper and Swanson 1990; Forrester 1992).

References

Draper, F. and M. Swanson. 1990 Learner-directed systems education: a successful example. *Syst. Dyn. Rev.* 6(2): 209-213.

Forrester, J. W. 1990. *System dynamics as a foundation for pre-college education.* Cambridge, MA: Mass. Inst. Of Tech. (D-4133), 18 pp.

Forrester, J.W. 1992. *System dynamics and learner-centered learning in kindergarten through 12th grade education.* Cambridge, MA: Mass. Inst. Of Tech. (D-4337), 20 pp.