Learning about Systems Dynamics: One Experience
by Diana M. Fisher

I was supposed to catch the Starlight at noon to return to Portland from Eugene. The 1990 NCCE conference had been held in Eugene in March. I had asked the courtesy car to pick me up from my last workshop at 10:30 so I could be sure to make the train. I probably shouldn't have tried to fit in the last workshop. It was scheduled from 9 to 12. But the topic seemed interesting... "Modeling using the STELLA Program." I thought I could at least get some idea of the material, or the technique in the hour or so I would be able to attend. What a fortuitous decision. I was captivated, within the first 15 minutes, by what I saw demonstrated. Luckily I was able to receive the handouts and the demo programs. It was a start.

When I returned to Portland I decided to purchase the STELLA program. AT $200 It was no small decision. I didn't even tell my husband, because I thought he'd argue me out of it. When the program and materials arrived I started to read the manuals. They were well written, but I didn't understand fully what I was reading. I became interested in some of the examples and even more excited about the potential for what students might be able to create. I started talking to some of the teachers at Franklin High School, where I taught. There was some interest, but it was my first year there and most of the teachers didn't know what to make of me let alone a new idea about modeling systems.

I decided to write an in-district "Technology on the Teacher's Desk" grant in April. These grants were easier to get than others but they were still competitive. I started to twist some arms to get at least 5 other teachers to agree to try to do something with STELLA in the next three years. I wanted to have a cross-curricular approach to the effort, so I was able to get two other math teachers, two science teachers and one social studies teacher somewhat interested. The idea must have been well enough defined, because we were awarded the grant ($12,000) which bought us not only STELLA but some much needed computer equipment - like the first laser printer and overhead panel display accessible to all the teachers. This helped my reputation with the other teachers, even though they knew nothing about system dynamics. Some of the grant readers in the district became interested.

There was disappointment and encouragement that first year (1990-1991). As the project leader I tried to learn enough to prepare some materials to help the other five learn with less effort. It wasn't enough. Only one of the other teachers and I were able to continue to progress without a real teacher to help us. I just could not learn the material fast enough to help the other teachers over some of the more difficult problems creating some of our early models. I did, however, continue to talk informally to teachers about system dynamics. I also communicated with teachers (in other parts of the US.) who had been using STELLA to get some ideas for resource material. That's when I purchased Nancy Roberts' book, "Introduction to Computer simulation: A System Dynamics Modeling Approach". This book helped me a great deal. It was so easy to read! And the examples were terrific! What a great book. (Then it was out of print a year later - a significant problem, since it was the one best resource for high school teachers that I had found.)

I attended the Third Annual NERD conference during the fall of 1990. The NERD conference was the brainchild of an exceptionally talented physics teacher in the district. With seed money from his Presidential Award for Science Teacher of the Year in Oregon, he set up a remote retreat for fifty science teachers (and some math teachers) in the Portland School District to share how they were using technology in their classrooms. It was at this retreat that I pulled a few science teachers aside and showed them STELLA.

Another seed was planted. (I will be giving the keynote address this year - 1992- at the 5th annual NERD - on STELLA and system dynamics in math and science.)

For the most part. I studied, wrote letters and gathered material from teachers the first year (1990-1991). I demonstrated the population model (from the second chapter of the STELLA User's Manual) to my second year Algebra class during the spring of 1991. A student who had not done well in the class commented, ""Why didn't we do something like this earlier? This I can understand." I had anticipated that the visual nature of the STELLA interface would reach certain students better than the traditional equation approach. This comment was reinforcing.

The next major leap occurred when I heard about the STACI project, and heard that they were going to have a one week work session at Stanford in June 1991. I called the director and pleaded to be allowed to audit. With much effort and a great deal of compromise as to what my audit would allow me to do, I was permitted to attend. It was there that I met the HPS people (who were very supportive) and other teachers who were open and willing to share what they could with me, especially Paul Dye and the Arizona contingent. Unfortunately, Frank Draper was not there. (As it happened, Paul Dye and some of his students had been invited by the NCCE program committee to do a presentation in Portland in the spring of 1991. I made a point to seek him out and talk to him about what he was doing and about the STACI project.)

In the fall of 1991, I wrote another in-district grant for expanding STELLA more into the social studies area. This grant money was distributed at the discretion of the Director of Instruction for our cluster. (Portland has so many schools in the district, they are divided into clusters.) He was not sold on the idea and wanted a demonstration. I demonstrated what we wanted to do with STELLA and dynamic modeling to him AND my principal and curriculum vice-principal. He awarded only half the money from the grant - but the principal and the vice-principal liked the idea so much, they paid for the rest from the building funds. It has been the continued support of the academic vice-principal, Mike Hryciw, that has made a difference for me. I felt my efforts were being recognized and my work appreciated.

We finally were able to purchase a full lab set of STELLA. We started to make some progress, but I quickly realized one important component I had left out of the grant - release time. It was very difficult for the teachers who already had full teaching loads, and coaching responsibilities, to find extra time to devote to learning something that was not as easy to learn as it first appeared.

I introduced STELLA in both my BASIC and Pascal programming classes. I knew I needed some significant time with students to determine how to teach the method and develop materials. Since I teach four classes a day, with four different preparations, and am the computer coordinator for a school of 1500 students, it had been difficult to find enough time to do what I needed to do to increase the speed of my learning. I spent a month on SD in each class. It allowed me to focus on my own understanding of system dynamics. I found I had to redo explanations from the User's Manual for my students. The questions they asked caused me to try to find underlying principles to help guide them. There was no substitute for this time. It was invaluable in the progress I made. I didn't want to just use other teachers' models. I wanted to be able to create my own, and I wanted my students to be able to create their own. I also was able, because of this focus time, to create some lessons for m, to create some lessons for my second year algebra students, which dovetailed nicely with the standard curriculum. (Second year Algebra starts usually with a review of linear functions. It was at the end of this section that I taught the algebra students enough STELLA to create some simple linear models. A

month later, when we had been studying quadratics, a question arose about linear growth versus quadratic growth. I started asking the students questions about the equation of a line and which part indicated the growth and what it meant. I was disappointed when so few students were able to remember our previous work. Then I decided to ask the questions using STELLA notation. The response was significantly better. The students remembered the diagram notation. They remembered the flow-stock ideas. They could explain why growth was linear using this method. The visual approach had made its impression.)

During the 1991-1992 school year, I made 8 to 10 STELLA presentations, mostly at math and computer conventions in the northwest. It seemed every time I talked to a group of teachers informally, I was talking about STELLA and system dynamics. I became very boring to be around, with my single-minded focus. But I couldn't seem to help myself. The more I learned, the more relevant the approach seemed.

In the spring of 1992 I attended the first annual Systems Thinking in Education Conference in Tucson, Arizona. For the first time I was able to meet people I had just talked to on the phone or written. It was very exciting for me to meet the people who attended. I returned renewed and excited to continue the struggle. I also was able to convince the curriculum council at Franklin that a one semester course in Mat Modeling (focusing on system dynamics) was perhaps one way to do cross-curricular modeling. I'd train the students and have them do projects for the teachers who had an interest but not enough time to model themselves. Lastly, I started to meet some people outside of education, in the Portland area, who were actually using STELLA to do real modeling in their work. These three occurrences pushed the effort ahead in great strides.

I was strongly encouraged to write an NSF grant to train teachers in the use of system dynamics. I had taught a one credit course for teachers in the spring of 1992. With that experience, my own struggles, and some experience teaching students, I felt I had enough information to put together some useful ideas for a training program. I was fortunate in that I now had interest from some teachers I felt could really cause the progress to quicken and who had excellent reputations as teachers and curriculum writers. During the process off writing the grant (which took me two months in the summer*) I found myself talking to more administrators in the Portland district, to gain their support. I also talked to more industry people who were interested in participating in the grant. This process raised the visibility of the effort we were making to try to incorporate system dynamics in our classrooms. The grant is pending. We hope to hear the results within the next few weeks.

A STELLA users emerged from the contacts made in the grant writing process. Currently we have about a dozen persons - 7 from industry, 3 university professors and 2 high school teachers - attending. We voted to expand this group.

Even if we do not receive the grant, I believe the critical mass of teachers and researchers has been formed. Our progress will be slower without the grant, but we will work to continue to change our courses to incorporate a more systemic look at certain problems. Attacking dynamic problems with linear, short-term "solutions", teaching compartmentalized information - it seems so unreasonable. I know I cannot go back to the way I used to teach. But the road ahead will not be easy. It is hard to change the way we teach. Schools will need to be structured differently. the task is to force the change to occur and to determine how to operate in the transition. We are not where Orange Grove is with Frank Draper's expertise, but we are making progress.

The resources that have helped me the most (besides the people who have helped me) are:

1. Nancy Robert's book, "Introduction to Computer Simulation: A System Dynamics Modeling Approach"
2. The STELLA II Manuals
3. MIT Pre-college materials
4. Systems 1: An Introduction to Systems Thinking by D. L. Kauffman
5. The Fifth Discipline by Peter Senge
6. Selected articles from "The Systems Thinker" newsletter.
7. The Global Citizen by Donella Meadows

(I have recently purchased Jay Forrester's books, "Principals of Systems" and "World Dynamics". They have not arrived yet.)

*Portland School District did supply me with a very capable grant writer, without whose expertise I would not have attempted to write a grant of such proportions.

Lees - go to next page.

NSF Grant Summary for
Cross Curricular Systems Thinking and Dynamics Using STELLA
(CC-STADUS)
Awarded 5/7/93: $7644,971 for three years

Project Summary:
Portland Public Schools' three-year Teacher Enhancement Program will improve education in mathematics, the sciences, and technology by training teachers to use an interdisciplinary systems approach and a sophisticated but simple-to-use modeling software called STELLA. (Systems Thinking, Experiential Learning Laboratory, with Animation). Each year 35 teachers will attend a three-week summer Leadership Institute exploring the use of STELLA to model complex and dynamic phenomena, relationships, and problems (such as global warming, population growth, food webs, or heating and cooling systems). Participants will practice developing models and supporting materials, and will be required to provide follow-up presentations on STELLA modeling for other teachers. A core team of teachers with particular interest/skills in modeling and curriculum development will provide ongoing support and will devote at least two weeks during the school year to developing, refining and disseminating materials. A two-day training for 30 teachers in years 2-3 will examine strategies for using STELLA among at-risk and under-represented student populations. Bringing together science, math and social studies teachers to be trained in computer modeling and systems thinking is designed to promote greater emphasis on the "real-world" applications of science-related knowledge, and on integrated educational approaches.

Goals & Objectives:
The CC-STADUS Teacher Enhancement Project will implement, evaluate and disseminate an innovative training model designed to improve the ability of math, science and social studies teachers to use computer technology in order to expose their students to complex problems and topics that cross traditional curriculum areas and have compelling "real-world" applications. The project's long-term goal is to promote the use of computer-generated modeling of dynamic phenomena, relationships and problems as an integral part of the school curriculum, rather than as an "add-on". To promote a paradigmatic shift toward systems thinking and dynamics, the CC-STADUS Project will pursue the following major objectives over three years of support from the National Science Foundation:
1. To train a cadre of at least 100 math, science and social studies teachers to use computer modeling techniques, to implement effective and cross-curricular classroom lessons based on computer modeling, and to serve as peer trainers of other teachers in their schools.
2. To develop a core team of approximately 22 math, science and social studies teachers to refine and disseminate computer models and supporting curricular materials, and to provide ongoing assistance regarding the use of computer modeling to study topics related to math, science, technology and society.
3. To promote the use of computer modeling and interdisciplinary systems approaches among minority, female, disabled and under-achieving or "at-risk" students.
4. To develop partnerships with business, industry, higher education and other public and private organizations to support the integration of computer modeling into the school curriculum.

Some of the project's expected benefits and outcomes will include:
- Each year 35 teachers will learn to integrate computer modeling into their classroom instruction. The tool (STELLA II) will help them demonstrate traditional curriculum topics in new ways. It will also allow them to introduce new and more complicated topics, ones which cross traditional disciplinary boundaries and encourage students to exercise critical thinking and problem-solving skills. It will help students explore basic math/science concepts and processes and their relation to society and everyday life. It will support a shift toward cooperative and small-group classroom activities, active student engagement in learning, and multi-level instruction that accommodates a wide range of learners. It will the teacher's role from dispenser of information to coach and catalyst.
- A network, or core team, of teachers with particular interest or skills in STELLA modeling will be prepared to serve as curriculum designers and resources for their educational peers, to ensure that effective modeling techniques are disseminated and used correctly.
- Cross-curricular computer models and supporting materials appropriate for pre-college levels will be developed, collected and disseminated.
- The project's "train the trainers" format, plus the development of mechanisms for ongoing access to both personal and electronic networks, will encourage continuation and dissemination of the knowledge, skills and strategies project participants acquire.

Project Focus & Significance:
The CC-STADUS Project will train high school teachers from the Portland, Oregon area (year one), from around the state(year two), and from around the region (year three), to use the STELLA II computer software program as an effective instructional tool. This tool, with its model-building and simulation capabilities, will enable teachers and their students to understand the dynamics generated by systems of interdependent relationships and phenomena.

The major strategies for encouraging use of STELLA II among classroom teachers will be a three-week "train-the-trainers" Summer STELLA Leadership Institute held each year, and the identification of teacher core team leaders who will ensure that appropriate materials are developed and used effectively in school classrooms. In the second and third years of the project, a special two-day workshop will be added, focusing on the use of STELLA among under-represented and "at-risk" student populations.

Core team teachers will come together for at least two weeks each year to work with STELLA II software to design models and curriculum materials for use in training other math, science and social studies teachers. The first year there will be eight core team leaders (three in math, three in social studies and two in science). The core team will be increased each year after the summer training.

Teachers who have attended the Summer STELLA Leadership Institute and who wish to become core team members must agree to:
- help provide training at the following year's Summer Institute;
- attend the two-week curriculum development sessions during the regular school year and develop 3-5 models, supporting tutorials and other interactive materials for dissemination to other teachers;
- utilize STELLA-based units in their classrooms (once each quarter in at least two classes);
- provide guidance and assistance for teachers who request help in using STELLA;
- attend once-a-month meetings with other core team members.

"NERDNet" is an existing electronic computer network and bulletin board set up by a Portland Public School high school science teacher. It will be used to communicate and share information easily on an ongoing basis. Computer models developed for STELLA will be stored on NERDNet, so they can be widely accessible. Core team members will also be given access to the Internet.

In July each year, an intensive three-week training workshop on STELLA will be held in Portland, Oregon, at Franklin High School, for 35 math, science and social studies teachers. To encourage participation, teachers will be able to receive a stipend, college credit, and (as needed) room and board. Core team members, principal investigators and consultants will assist in training the teachers. To participate, teachers must have access to a Macintosh computer. Participants will each be provided with one copy of the STELLA II software to use in their schools. Project recruitment and selection activities will seek to ensure that a diverse group is selected each year in terms of ethnic/cultural background, gender, content areas, and course levels taught. Teachers who wish to attend the summer workshop must be willing to:

- share what they have learned at the STELLA Leadership Institute at a faculty inservice presentation in their buildings;
- utilize the units they received at the Summer STELLA Leadership Institute in at least two of their classes (core team members will assist them in designing evaluation instrument to assess how students responded to the units);
- develop 2-3 additional models using STELLA and then send them (by the end of the first semester of the following school year) to the core team, which will in turn fine-tune them and make them available to other teachers who are using STELLA.

The summer training will focus on learning to use the STELLA II software in individual curricular areas the first week, exposure to and practice with models developed by training consultants the second week, and in the third week the design and implementation of cross-curricular models and curricular materials.

How Research has Influenced Project Design:

Teacher Change: While it has become commonplace to assert the central role of teachers in educational reform, any proposed changes are likely to fail if imposed on teachers from outside or from the top down. As Stanford University professor J. Myron Atkin has observed, "Not much progress in education is likely to take place unless teachers become agents in the improvement of their own practice."

Math: One of the central NCTM tenets is that all students need greater opportunities to explore basic mathematical topics, even though some students will explore them in greater depth and at higher levels of abstraction. While modeling is central to mathematics and teaches students strategies and skills that are easily transferred to situations in the world outside the classroom, high school teachers have tended to avoid large areas of modeling because of the complexity and tedium of mathematical equations involved. STELLA provides compelling evidence of how technology can transform learning.

Science: The project also supports the movement toward concept-based science instruction, which is designed to enable students to master the basic scientific ideas that will allow them to evaluate and solve problems they may encounter in later education and life.

Integrated science-math-social sciences focus: The current interest in multi-disciplinary education is part of a general awareness among professionals and thinkers from all walks of life - scientists, economists, government planners and policy makers, etc. - of the interdependency of various fields, and of the importance of looking at webs of relationships, at the interactions operating in a given system, and at patterns. We are more likely to understand a particular concept if we can see its application to a variety of disciplines and "real-life" situations. Professional organizations such as the National Council for the Social Studies have conceded that new technologies have not been addressed adequately in the social sciences, and that this field needs to address inquiry process more effectively, and how technology supports inquiry. Because of the importance of critical thinking skills in social studies, STELLA offers the capability to take data and use it in comparative ways so the questions can be formulated and hypotheses tested. Modeling will enhance students' appreciation for the interconnections between the social sciences and other disciplines, and will allow them to evaluate alternative solutions to various problems found in human society.

Evaluation Plan:
The evaluation will be conducted by the Northwest Regional Educational Laboratory (NWREL), an independent, nonprofit research and development institution located in Portland, Oregon. NWREL will collect data by observing training activities, interviewing and surveying the teacher participants and the business partners, analyzing the curricular materials and computer models, and observing classroom use of computer modeling.