the Creative Learning EXCHANGE

Volume 6, Number 1 - Winter 1997

QUALITY AND SYSTEM DYNAMICS/SYSTEMS THINKING: INTEGRATING THEM IN A MIDDLE SCHOOL

by Joan Yates, Catalina Foothills School District System Dynamics Project

The quality movement in this country has heretofore taken place primarily in business and industry. Within the past five years or so, however, an increasing number of educators have been thinking, speaking and writing about applications of quality principles, particularly those espoused by W. Edwards Deming, in schools. Educators have also fairly recently been investigating ways to incorporate some of the thinking and practices from the fields of system dynamics and systems thinking, both previously applied more in the domains of business and post-secondary education than in K-12 education, into classrooms and into the running of their schools and school districts.

Staff members at Orange Grove Middle School in Tucson, Arizona, have been integrating some of the key practices and principles of total quality, system dynamics, and systems thinking within their school for the past five to seven years. The author provides examples of applications of this integration within an eighth grade writing and literature class and within the organization of the school.

INTRODUCTION

As a staff member at Orange Grove Middle School of the Catalina Foothills School District in Tucson, Arizona, and as the manager of the district's System Dynamics Project, I have participated in the implementation of programs and practices within the last five to seven years that integrate principles of quality with principles and tools of system dynamics (SD) and systems thinking (ST). Originally, we at Orange Grove did not actively seek out the writings, input, or influence of some of the leading thinkers in these fields–W. Edwards Deming, Jay Forrester, Barry Richmond and Peter Senge–but have nonetheless over time created, adopted, and revised structures and practices that represent an integration of some of the principles of each field.

In the spring of 1988, two events happened concurrently in our school district. One was the decision to transform Orange Grove from a junior high into a middle school. The other event involved community member, and Dean Emeritus of MIT's School of Engineering and Institute Professor of the Department of Electrical Engineering, Dr. Gordon S. Brown's sharing of the STELLA® software (Richmond, Peterson et al, 1988) with eighth grade science teacher Frank Draper. Unbeknownst to us at the time, the combination of these two seem-

***Quality** continued on page 3*

Bears and System Dynamics

by Tom Bulka,

The class I did this project with is a Computer Programming II class. The prerequisite for this class is Computer Programming I...basically a semester of Pascal. The quality of the students was average for our school, grades in the Pascal class ranged from high 80's to low 70's ...actually high 60's but I'm easy! The point being that even for my school, these students were not the most intelligent/motivated. A total of 6 students were in this class. The small class size was definitely a plus.

Students were quite excited about using/learning Stella. Initially, we spent one period talking about systems, having the students give examples of systems and writing written descriptions of the systems on the boards These descriptions tended to be things like, "you got deer, deer have babies, they eat food, they get eaten and they get shot by us during hunting season". What I then did was to replicate the word description with a model of how it would appear in Stella... so the "you got deer" became a stock, etc. I'm wasn't quite sure how well they understood, they shook their heads (as they always do) when asked if they did, so I decided to go to the next step.

***Bears** continued on page 11*

Updates. . .

Ridgewood NJ

From Tim Lucas

My focus has been the infrastructure of the school and classrooms. I have created with parents, teachers, and students, goals and processes that allow us to handle change in the school. Including how the school can continue to grow as a learning organization and community without me as principal. As I explore that idea with parents, it empowers them to be active participants in all of the opportunities I provide (facilitate) toward the focus/passion of the school. Parents are always involved with the interview process for new principals so the clearer each parent can model the infrastructure of our community the better they can help match the right candidate to the position. (I'm not leaving-I'm just lining up my ducks so my work or our work as a community, can continue.) Since change is on-going and more complex, we have to plan for transitions and build an awareness of all the transition we go through in our lives and (here's the hard part) the willingness to change."

Things are going well. The teachers continue to create and use maps and models with students and parents. There is a definite comfort level and "soul" in the building. I'm told you can feel it when you walk in.

Some of the other principals are becoming more involved-and the middle school and high school are working more and more with Inspiration and STELLA. Rich (Langheim) has coordinated on-going staff development courses using middle school teachers as instructors. So the effort is still strong.

CC-STADUS Project

For those of you who would like an update and current description of the CC-STADUS project in Portland Oregon, here is a description written as an answer for the K-12 discussion group:

The CC-STADUS project (a National Science Foundation funded institute) has been involved in training secondary teachers in computer modeling for the last 4 years. In that time we have trained approximately 160 teachers who have, in turn, presented workshops or short sessions for another 1500+ teachers. Those teachers who have participated in our program have developed a number of interdisciplinary and single subject models. Many of these models have been released through our own web page and through the Creative Learning Exchange.

Our participating teachers receive 12 days of training (8 hours each day) during the summer. They have the option of receiving 6 hours of credit from Portland State University. This training focuses first on the use of STELLA software (4.5 days), then roughly 4 days are spent looking at how modeling/system dynamics is used in industry, research, and higher education. Finally, the remaining time is spent developing a major interdisciplinary model and accompanying curriculum in collaboration with at least two other teachers.

When we began the project STELLA seemed to be the most commonly used software in systems. Since then other options have emerged. However, our most skilled modelers have found that STELLA is the easiest to teach other teachers and students to use. The basic structure of STELLA models seems to be more intuitive than similar models in other software. Some of the other packages are undeniably more powerful and versatile. However, ease of use, ease in learning, and the range of materials already released for k-12 education are powerful arguments for continued use of STELLA. The greater power and versatility of the other software will not generally be useful at the k-12 level. Whether or not they would be desirable for undergraduate or graduate use would depend on the systems being modeled.

***Updates** continued on page12*

From the Editor . . .

Having just finished up last summer's conference, we are in the midst of planning the summer conference for 1998. As you can see elsewhere in the newsletter, we have found a location and set a date. We are having it at the New England Conference Center on the University of New Hampshire campus. They offer wonderful facilities, accommodations and food.

The dates are the last Sunday, Monday, and Tuesday in June (June 28-30.) If people are traveling from a distance, they can take advantage of less expensive air fares and stay over on Saturday night. We were energized from the last conference and are looking forward to an equally successful one in 1998.

The school systems around the country are maintaining their momentum. The CC-STADUS project has added a systems strand as a magnet in two high schools in Portland. Along the same vein, WPI is offering undergraduate course sequence in system dynamics (see article).

We are continuing to offer the newsletter via three methods: 1. E-mail notification of availability on the WWW. 2. E-mail with an Acrobatted newsletter as an attachment and 3. US mail. (Lastly because it is the most expensive for us.) If any of you wish to switch methods of receiving it, please notify us.

Have a lovely spring.

***Lees Stuntz** (stuntzln@tiac.net)*

Quality and Systems Thinking continued from page 1

ingly unrelated events proved to be a major catalyst in the formation of what is now a middle school that applies many of Deming's fourteen principles (Blankstein, 1992, 71) and four components of profound knowledge (Rhodes, 1990, 34), Jay Forrester's and Barry Richmond's work in the field of system dynamics, and Peter Senge's concept of the five disciplines of a learning organization, particularly the fifth discipline of systems thinking.

DEMING'S QUALITY PRINCIPLES AT ORANGE GROVE

Over the years, the Orange Grove staff has never undertaken a study of, or even a discussion of, Dr. Deming's work. Having said that, though, I must emphasize that what we are doing, and have done over the years, is work to create constancy of purpose for improvement of product and service; improve constantly and forever every process; institute training on the job; adopt and institute leadership; drive out fear; break down barriers between staff areas; eliminate slogans, exhortations, and targets for the staff; remove barriers that rob people of pride of workmanship; institute a vigorous program of education and self-improvement for everyone; and put everybody in the organization to work to accomplish desired transformation (Blankstein, 1992, 71)–ten of Deming's fourteen principles.

There are specific actions and/or structures that we as a community of staff, students and parents have instituted over the years to implement each of the principles, but within the scope of this paper and its topic of integrating quality principles with system dynamics and systems thinking, I will focus particularly on the principle of breaking down barriers between staff areas. (If you are interested in learning more about philosophy and practices at Orange Grove that I believe are consistent with Deming's principles, you can consult <u>Structuring Schools for Success...A View from the Inside,</u> Vol. 11 of the Total Quality Education for the World's Best Schools series, a book written by my Orange Grove colleagues Mary Scheetz and Tracy Benson about work done there in the past five years.) (Scheetz and Benson, 1994)

In addition to the ten listed principles, the OG community incorporates Deming's systems component of profound knowledge–"Deming believes organizations are systems whose 'functions or activities work together for the aim of the organization,' " (Rhodes, 1990, 34) as well as his "PDSA (Plan-Do-Study-Act) cycle" (Schmoker and Wilson, 1993, 392) into our work, as I will elaborate on in the "Quality and ST in the Organization" and "Quality, SD and ST in the Classroom" sections of this paper, respectively.

SYSTEM DYNAMICS AT ORANGE GROVE

From the moment Dr. Gordon Brown stepped onto the Orange Grove campus to talk with Frank Draper and share the STELLA® program, we at Orange Grove have been learning about and applying our knowledge of system dynamics, both within the classroom with students and as staff members working together within a learning organization.

System dynamics is a field created by Dr. Jay Forrester, who had been a graduate-student staff member at the MIT Servomechanisms Laboratory under Dr. Brown's directorship in the early 1940's.

In Dr. Forrester's words,

> System dynamics provides a way to understand how things change through time. Most problems and their solutions involve change...System dynamics is more than a set of tools. It provides a philosophy and a way of looking at the world to understand better how the past led to the present and how present actions control the future. But system dynamics goes much deeper than just talking about systems. It builds on the strength of people's experience and knowledge. System dynamics compensates for the major weakness in customary decision making by showing how the pieces of the system that we know about are producing the behavior that is so puzzling. Such greater understanding comes from organizing our knowledge of the parts into computer simulation models that allow observation of how the parts interact...System dynamics provides a dynamic framework into which students can place detailed knowledge. (Forrester, 1994)

Since 1988, students and staff at Orange Grove have built and/or run computer simulation models that facilitate study of how parts of various social, biological, and environmental systems interact. In addition to computer models, we have used other system dynamics tools to show, among other things, how the pieces of the system that we know about are producing behavior that may be puzzling us. (Forrester, 1994) In the "Quality, SD and ST in the Classroom" section of this paper, I will elaborate on the use of the SD tool known as a behavior-over-time graph (BOTG) in an 8th grade writing and literature class, and how the use of this tool was integrated with a variation of Deming's PDSA cycle, as students worked to improve their individual performance in class.

SYSTEMS THINKING AT ORANGE GROVE

The terms "system dynamics" and "systems thinking" are inextricably linked. In his paper "Systems thinking/system dynamics: let's just get on with

Quality *continued on next page*

Quality and Systems Thinking continued from page 3

it," Barry Richmond (1994), one of the creators of the STELLA® software, attempts to clarify what system thinking is and is not. As for what systems thinking is not, Richmond says,

> Let me begin by briefly saying what systems thinking is not. It is not General Systems Theory nor soft systems nor systems analysis, although it has elements in common with all of these. Furthermore, systems thinking is not the same as chaos theory, dissipative structures, operations research, decision analysis, or what control theorists mean when they say system dynamics, although, again, there are similarities in subject matter and methodology. Systems thinking is also not hexagrams, personal mastery, dialogues, or total quality. (Richmond, 1994)

Richmond goes on to state what systems thinking is.

> The definition of *systems thinking* at which I have arrived is the following: systems thinking is the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure. (Richmond, 1994)

Peter Senge, in his book The Fifth Discipline: The Art and Practice of The Learning Organization, describes systems thinking in this way:

> The essence of the discipline of systems thinking lies in the shift of mind:
>
> - seeing interrelationships rather than linear cause-effect chains, and
> - seeing processes of change rather than snapshots
>
> The practice of systems thinking starts with understanding a simple concept called "feedback" that shows how actions can reinforce or counteract (balance) each other. *It builds to learning to recognize types of "structures" that recur again and again*...Eventually, systems thinking forms a rich language for describing a vast array of interrelationships and patterns of change. Ultimately, *it simplifies life* by helping us see the deeper patterns lying behind the events and the details. (Senge, 1990, 73)

A common component of Richmond's and Senge's definitions of systems thinking involves identifying and understanding underlying structure. In our case at OG, we have looked at the interrelationship of parts and the underlying structures of the system both within a classroom and within the organization that is the school. Having done some of the initial identification of interrelationships and structure, and having some understanding of the underlying structure that is in place, we have gone on in many instances to examine whether the structures that are in place are helping us achieve our desired results. When we've found that certain structures aren't helping us, we have then worked to determine what structures we think are most likely to facilitate our achieving the desired results, keeping in mind both short-term and long-term effects of potential changes in infrastructure.

INTEGRATING THE PRINCIPLES OF THE THREE FIELDS

Deming's, Forrester's, Richmond's and Senge's thoughts overlap, particularly as they emphasize the importance of identifying the parts of a system in which you are working, or which you are studying, and recognizing the interrelationships of those parts and the behavior generated as a result of those interrelationships.

Although Deming is primarily associated with the "quality movement" and his 14 principles, his thoughts about systems as one of the four components of profound knowledge provide the link between Forrester's, Richmond's and Senge's systemic view of the world and Deming's belief about the systemic nature of an organization**:**

> Management of a system requires knowledge of the interrelationships between all the components within the system and of the people who work in it...The greater the interdependence between components, the greater the need for communication and cooperation between them...All the people that work within a system can contribute to improvement, and thus enhance their joy in work. (Rhodes, 1990, 34)

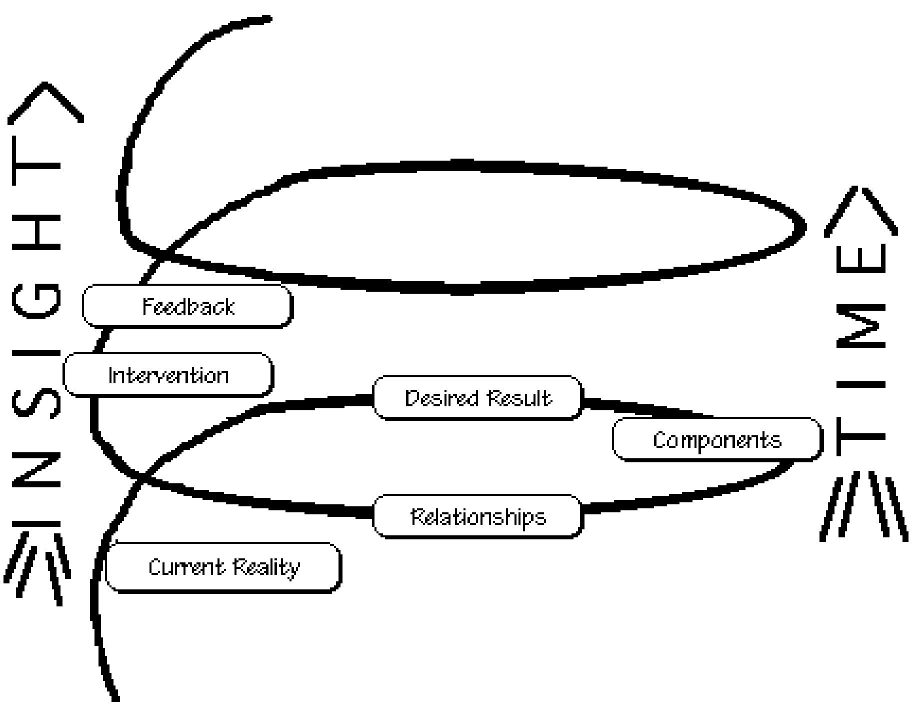
Dr. Deming's statements illustrate the advantages of working together productively within a system–enhancing one's joy in work–as well as some of the challenges presented by taking a systems view of a working or learning situation–a greater need for communication and cooperation. What is left to us at Orange Grove and to practioners in all organizations who believe in the principles of quality, system dynamics and systems thinking, is to find ways to incorporate those beliefs into our daily work.

QUALITY, SD AND ST IN THE CLASSROOM

One example of the melding of quality principles and system dynamics within a class at Orange Grove comes from Ron Michalak's eighth grade writing and literature class. Mr. Michalak and I, neither of whom was familiar with Dr. Deming's work at the time but who both had been members of the Orange Grove staff throughout the years in which we've been learning about and implementing SD and ST, created an adaptation of Deming's Plan-Do-Study-Act cycle (Schmoker and Wilson, 1993, 392) four years ago which we called Slinky® Theory©, referencing the name of the popular Slinky® toy**.** Michalak uses Slinky® Theory© with his students/has his students use applications of the theory throughout the year in a variety of ways.

The theoretical basis for Slinky® Theory© is Forrester's/SD's "a way of looking at the world to understand better how the past led to the present and how present actions control the future," (Forrester, 1994) as well as Senge's/ST's "seeing relationships rather than linear cause-effect chains, and seeing processes of change rather than snapshots." (Senge, 1990, 73) Michalak and I wanted to illustrate to a group of adults with whom we were working that a person or group of people never covers exactly the same ground when repeating the process of observing current reality; determining desired results; identifying components of the system in which the work will be done and the relationships between those components; acting, or performing some intervention; getting feedback and/or seeing how feedback within the system affects the outcome of the actions taken; and then beginning again by observing what the new current reality is after having gone through one "loop" of what we believed to be a circular cycle. (Note the parallels between these steps of Slinky® Theory© and Deming's PDSA cycle.) Being teachers who appreciated the value of "visuals," we hit upon using the Slinky® I had at home as a physical representation of a continuous, repeated circular pattern around which you could move without covering the same ground, i.e., touching the same link of the Slinky®.

Pictorial Representation of Slinky® Theory©



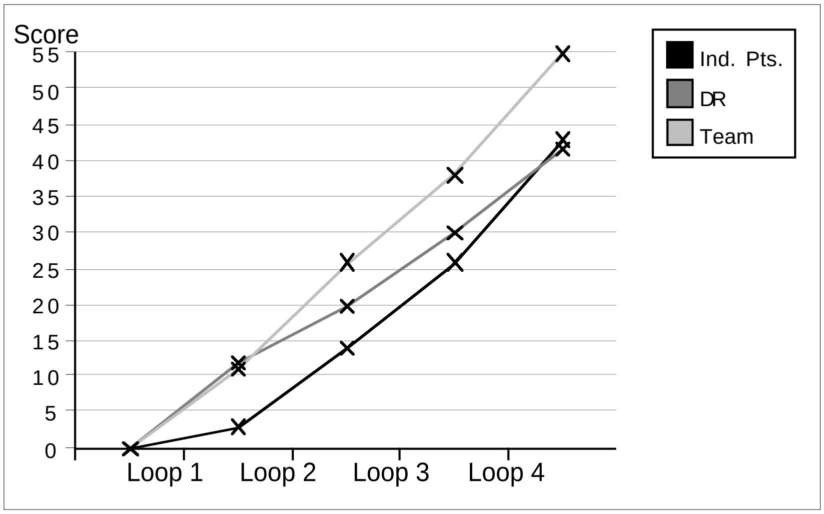
One application of Slinky® Theory© in Michalak's class combined the theory with use of the SD tool behavior-over-time graph (BOTG) as the students completed a propaganda game used in the propaganda unit within the non-fiction component of the literature course. Michalak let his students know what the "desired result" was, i.e., what it would take by the end of the game to achieve a grade of "C." The students had also taken notes on what the "components" and "relationships" were in the game, and on what actions/"interventions" they could take in the game in order to score points. Then, after the students had completed two "loops" of the game, they made BOTGs on the computer by inputting their scores and the scores necessary at that point to be achieving the desired result for a passing grade. By doing this, the students were able to "see" how they were doing.

As a system dynamics tool, BOTGs are designed to help students begin to see how things change over time. By graphing their scores relative to the desired results, students could see how they were faring over time as the game progressed. Michalak's assumption was that having that feedback would improve the accuracy of each student's assessment of his/her "current reality" in the game, and would help them as they chose what their individual actions/interventions should be in the next "loop" of the game, in order to achieve the desired results by the end of the game.

Quality *continued on next page*

Quality and Systems Thinking, continued from page 5

An Individual Student's BOTG (DR=Desired Result)



Michalak also used an additional intervention, along with Slinky® Theory© and BOTGs, creating another structure in the class which he felt would most likely help him achieve his desired result, which was that all students would demonstrate understanding of various propaganda techniques as shown by their passing scores in the game. The additional intervention included Michalak, myself, and Orange Grove's System Dynamics Mentor, Sam DeVore, working as personal "coaches" with students in the class who were below the desired result after the second "loop" through the propaganda game. Michalak and I put together a sheet which we three coaches would use when meeting with each student. The sheet listed information the students previously had been given about the "desired result," "components" and "relationships" intrinsic to the game and asked the students to write out the plan/intervention they would commit to trying in the next loop of the game in order to improve their performance, thereby bringing their score closer to the desired result, or perhaps surpassing the DR.

Sheet Used by Coaches with Students Who Scored Below the DR After Two Loops

Name________________
Coach________________

Propaganda Game Relationship Analysis Sheet

Components	Points	
Plurality	3	
Defend	1	
Challenge/good argument		2
Challenge/good argument/correct	8	

Above Desired Result Scenarios for Loop 1 and 2 **total**

#1	Pluralities - 6	Defenses - 5	Challenges - 5
#2	Pluralities - 2	Defenses - 2	Challenges - 6
Yours	Pluralities -	Defenses -	Challenges -

Action Plan for Loop ____ Using your graphs and the information above, what components will you affect differently in the next loop? What will be your new intervention? Write your plan on the back of this sheet.

Michalak was deliberately using classroom structures that employed system dynamics and systems thinking in order to facilitate his and the students' achievement of desired results. What he didn't know was that he was also integrating SD and ST with some of Deming's philosophy as applied to schools:

His (Deming) philosophy assumes an educational system in which desired outcomes are clearly defined and understood by all. The teacher's responsibility is to assist all students to improve processes toward achieving the outcomes...When problems arise, those directly involved...may form a *quality circle*. Rather than blaming any individual, they collect relevant data on the situation, define a possible opportunity to improve the process, test the change in the system, observe the results, and permanently implement the change, if it proves effective. (Sherkenbach, 1988, as quoted by Blankstein, 1992, 73)

In the case of "The Propaganda Game" in his class, Michalak established structures that would help the students and himself keep track of change over time, rather than waiting until the end of the unit to test students and give them a grade. He also provided information about the desired results at the very beginning of the unit, and created a version of quality circles that included himself, each student who was performing below the DR level, and a personal coach for each student. The interventions with the coaches began after the second loop through the game. At the end of the third loop, the coaches and students met again, and some coaches also met with individual students during loops three and four.

Using the "coaching" structure throughout loops three and four of the game melded the quality steps of "...define a possible opportunity to improve the process, test the change in the system, observe the results, and permanently implement the change, if it proves effective..." (Blankstein, 1992, 73) with the system dynamics concept of "showing how the pieces of the system that we know about are producing the behavior that is so puzzling..." (Forrester, 1994)

As one of the coaches who worked with the students, I can assure you that they were puzzled about how/why they had the scores they did at the end of the second loop, and they were equally puzzled about how they might improve their performance and, therefore, their score. Once we used the "Relationship Analysis Sheet" with them, though, the students were able to accurately analyze how their previous actions, or lack of action, had generated their current scores and the students could go on to plan a course of action for the next loop of the game that should bring their score closer to the desired result. Only one of the six students with whom we worked in Mr. Michalak's class did not reach or exceed the DR by the end of the game, a result that far exceeded what Mr. Michalak's students had achieved the previous year when he did not use these interventions with the students. (The results were also better in the class in which we did use all three structures–Slinky® Theory©, BOTGs, and coaching with the Relationship Analysis Sheet–than in his class in which he only used the first two structures.)

QUALITY AND ST IN THE ORGANIZATION

A major change at Orange Grove in the past five to seven years has occurred in our perception of our school/ourselves as a system,

> ...a perceived whole whose elements "hang together" because they continually affect each other over time and operate toward a common purpose. The word descends from the Greek verb *sunistanái*, which originally meant "to cause to stand together." As this origin suggests, the structure of a system includes the quality of perception with which you, the observer, cause it to stand together...Some people think the "structure" of an organization is the organization chart. Others think "structure" means the design of organizational work flow and processes. But in systems thinking, the "structure" is the pattern of interrelationships among key components of the system. That might include the hierarchy and process flows, but it also includes attitudes and perceptions, the quality of products, the ways in which decisions are made, and hundreds of other factors. (Senge et al, 1994, 90)

As recently as school year 1988-1989, Orange Grove was a junior high school that scheduled students to see a different teacher for a different class every 45 minutes, and scheduled the teachers to have a 45 minute planning period sometime during the day, not necessarily with other teachers who taught the same subject or grade level. Under this organizational scheme, teachers came together in order to share information and make decisions in one of two basic groupings–as subject matter departments, e.g., the English department or the math department, and as a staff for whole group "faculty meetings." We did not have structures established to facilitate communication and, by extension, interrelationships among key components of our system–we were only having small group discussions with and consistently exchanging ideas with our colleagues who taught the same academic subject we did. The only other structured communication happened between the principal and the departments, via a department head or rep. There was no scheduled interdepartment communication, and therefore that type of communication, and the collaboration that could have come about as a result of it, did not happen consistently. We hadn't come to appreciate how interrelated we were as "components" of the system that constituted our students' formal educational system, and therefore weren't operating based on Deming's thought, quoted earlier, that "the greater the interdependence between components, the greater the need for communication and cooperation between them." (Rhodes, 1990, 34) We were definitely not viewing ourselves systemically in terms of how we were communicating.

Likewise, we stayed within the same structures when we made decisions. Teachers within any one department made curriculum and instruction decisions, as well as purchasing decisions, in isolation from teachers who taught other subjects. Staff members who were not classroom teachers were included in decisions only when something reached the stage of being a "whole school decision" that came up for a vote in a faculty meeting, unless they were responsible for an area of the school such as the library or counseling, in which case they made decisions about purchasing and policy in isolation, perhaps after consulting select colleagues, or in conjunction with the principal. The principal had the final say in most operational and budgetary decisions.

As with communication, decision-making was formally viewed as a fairly linear operation, with the line going from a department to the principal, or from the principal to a department. Fortunately, we had principals at Orange Grove in my first 11 years there who regularly chose to include some or all staff members in decisions, but there were no structures in place to expedite the consistent inclusion of all staff members, let alone students and/or community members, in formative and/or summative decision-making stages. Although Orange Grove was a "successful school," i.e., one in which our students consistently performed well academically and athletically in comparison to other schools in Southern Arizona, we had not come to perceive ourselves as a "...whole whose elements 'hang together' because they continu-

***Quality** continued on next page*

Quality and Systems Thinking, continued from page 7

ally affect each other over time and operate toward a common purpose." (Senge et al, 1994, 90)

Once we began the transition to being a middle school, we deliberately built in what I now recognize as Deming's ninth principle of breaking down barriers between staff areas. We did this physically as well as organizationally. Physically, we remodeled existing classroom pods so that each pod housed five classrooms and one common work area for the staff who would be working in that area. Previously, each pod had housed six classrooms, with no common area in the building for staff members. In fact, the only common staff area in the school was a small lunch room. Eventually each pod housed teachers who had job-alike assignments–teaching the same subject and/or the same grade-level students.

Communication among teachers teaching the same grade-level students became a focal point of our organizational structure, as it had of our physical structure. A common element of middle schools is that teachers and students form "teams." At Orange Grove we created grade level teams. One implication of that for the staff was that we built into our schedule a common plan time for all the teachers who taught the same grade level, allowing time for interdisciplinary planning that hadn't been built into the schedule previously. Now the team of seventh grade teachers, for instance, could meet together during the week to discuss curriculum they were presenting to the seventh graders in various classes, to discuss any concerns anyone had about a student, and to take care of "business matters" such as ordering of supplies, or making changes to the seventh graders' schedule for special events. What this scheduling of common plan time did was highlight interrelationships among teachers who shared experience with a common group of students, thereby focusing attention on experiences students were having throughout a day or week, not just throughout their years as a math or social studies student, as had been the case when most communication was done within departments.

In addition to grade level teams, we also created a "support" team and an "arts and foreign language" team, both teams being comprised of staff members who work with students "at large," i.e., not with students in a particular grade level. This meant that each staff member, whether s/he were the principal, custodian, health room assistant, art teacher, secretary, Spanish teacher, or librarian, was a member of a team that would meet regularly to discuss the work they were doing in the school and how their work related to the work of other teams.

Our growing understanding of systems thinking led us to study not only what structures we wanted to create in order for us to deliver the cohesive program we wanted to present to students through teams, but also challenged us to make, as Richmond says, "...reliable inferences about behavior by developing an increasingly deep understanding of underlying structure." (Richmond, 1994) One of the inferences we made about behavior at Orange Grove was that creating physical and scheduling structures that allowed us to work more systemically <u>within teams</u> did not necessarily give us the structures necessary for dealing with the feedback we wanted <u>between teams</u>, feedback that would inevitably come whether we were ready for it or not. We wouldn't be working intelligently as a system of interrelated parts if we didn't build in structures to accommodate <u>interteam</u> communication.

We've handled this communication challenge at Orange Grove by establishing "task teams" which are comprised of a member from each of the grade level, support and arts/foreign languages teams. Throughout the years, the tasks for which these teams were responsible have changed, based on our assessment as a staff of what the needs were within our system. (Some of the current task teams are Instruction and Assessment, School Environment and Culture, Student Welfare, and Technology.)

I mentioned in the previous paragraph that teams were "responsible" for certain tasks. The "responsibility" issue is one that I think has evolved over time at Orange Grove as we have learned more and more about systems thinking and system dynamics. Not only have we built structures at OG that facilitate communication, but by also giving teams the power and responsibility to make various decisions for themselves, rather than leaving those decisions for an administrator to make, we have integrated systems thinking with Deming's principles of quality. As staff members have more responsibility for the decisions made within the school, we come closer to achieving two more of Deming's principles of quality–the principles of driving out fear and removing barriers that rob people of pride of workmanship.

Each team now controls its own supply and travel budget, for instance, rather than having it controlled by the principal. This means that when team members meet during their common plan time or during a task team meeting, co-workers decide what can and should be purchased, or who can and should travel to a particular conference. As you might imagine, making such decisions is not always easy, but to truly understand how each person's actions, e.g., purchasing or traveling, affect one another within the system, the people within the system need to make those decisions, rather than having them made by an administrator who is one step removed from the team.

Likewise, for people to have pride in their work, they need to be doing meaningful work, which each team at OG does. For example, just last week the School Environment and Culture task team organized “shared vision lunches” for the staff during all three of the school’s lunch periods. Task team members planned the pot luck lunches and facilitated discussion during the lunch time in order to follow up on input the staff had generated at a December meeting regarding key components of our system that need attention in the second half of the year. Although the principal had led the December meeting, a task team of which she is not a member took over the coordination of continuing the important December discussion. Such roles of coordination and facilitation were once left to the administrators and to a few chosen staff members, but now every task team member–every staff member–recognizes that s/he is an essential component of the OG system and works to share the responsibilities of creating and maintaining a fine school program.

If a team begins to feel that they aren’t contributing meaningfully to the entire system, as in the past some task teams have felt, or if a team feels that they aren’t connected as they’d like to be with the work of another team, the structures are investigated to see if we need to make adjustments within a team, among various teams, and/or within one of our underlying communication or decision-making structures. Once again, staff members within their teams, including administrators within the support team and task teams they’re on, decide what issues to pursue and what structures to pursue them through. I believe this increased participation in decisions, and the responsibility that goes with it, helps each staff member understand the interrelationships within our OG system and helps us achieve a number of Deming’s principles of quality.

CONCLUSION

Although not having set out to do so, I believe that in a good deal of our work within the classroom and the organization at Orange Grove we have integrated key components of Deming’s quality principles and his thoughts on systems as a component of profound knowledge, with key elements of system dynamics and systems thinking. We want the OG students, staff and community to understand the systems in which they operate so they can make informed decisions throughout their lives, and we hope that we will all be part of systems that are doing quality work. I believe by integrating quality principles with SD and ST, we are attempting to do what I heard Daniel Kim, speaking at a systems in education conference in Tucson, attribute to Gandhi–“Be the change you want to see in the world.” (Kim, 1993) By making the changes we have at Orange Grove, and by staying open to “seeing processes of change rather than snapshots,” (Senge, 1990, 73) we are becoming the type of quality system we want to see in the world. We at OG recognize that we have just begun to see the benefits for students, staff and community that this integration of quality, SD and ST can produce, and we look forward to the challenges and opportunities we will discover as we continue this work.

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BIOGRAPHICAL SKETCH

Joan Yates is in her second year as the System Dynamics Project Manager in the Catalina Foothills School District in Tucson, Arizona. She has eight years experience teaching junior high school English and mathematics, three years experience as a junior high school administrator, and three years experience teaching writing and literature at Orange Grove Middle School. Both as a member of the Orange Grove staff and more recently as the System Dynamics Project Manager, Joan has collaborated with fellow staff members to implement concepts of systems thinking, system dynamics, and the learning organization within individual classrooms, the school, and the district.

Joan received her B.A. in English from the University of California, Davis.

Updates, continued from page 2

We strongly support your suggestion that a focus on relationships and patterns rather than mathematics is appropriate for initial training. Over the years our training has evolved to focus on developing an understanding and mastery of modeling structures that display a few basic behaviors: linear growth/decay, exponential growth/decay, s-shaped growth, and quadratic growth. Most of the phenomena studied in high school mathematics, science, and social science classes exhibit these behaviors. By focusing on the behaviors and the model structures that exhibit them, rather than on the traditional mathematics used to describe them, teachers develop a "feel" for the model behaviors and learn to look for them in real problems. The same should prove true for your students.

A major focus of the fourth year of our project is "polishing" and release of our training materials. This work should be done by the end of March, 1997. These materials will be placed in the public domain, and will be available through our web page and the Creative Learning Exchange. If you are interested, we will send them as soon as they are finished. We also have a continuation/dissemination grant request pending with the NSF. We anticipate continuing our training through this grant for the next three years. Along with continued work in the Pacific Northwest, a focus of this grant will be the training of cadres in three other locations in the United States. We will assist these cadres in establishing training programs/centers in their own area.

Ron Zaraza
Wilson HS CC-STADUS Principal Investigator

Other News from Portland

Franklin High School, where Diana Fisher is a teacher, has been designated a systems magnet school for math and science. Wilson High School, where Ron Zaraza is teaching, has been designated a systems magnet school for science and social studies. Ron and Diana have both been half time teachers and half time mentors this year. Their available time as mentors has made a visible impact on the schools around the area where systems education got a toe hold from the NSF grant. Hopefully, that extra resource for systems education will continue over the next several years.

Escambia County, FL

From Daniel Freeman, K-12 Science specialist

I am beginning to work with a core group of teachers to bring system thinking and dynamics to the Escambia County School District. One of our teachers (Kathy McMichael) was awarded a $33,00 "Break-the-mold" grant to implement system thinking/education into her school's curriculum. The award was for 15 pentium computers and the STELLA software.

System Dynamics at Worcester Polytechnic Institute, Worcester, MA

by Mike Radzicki

WPI is the third oldest college of science and engineering in the United States and offers degrees at the baccalaureate, masters and PhD levels. WPI's undergraduate program is quite unique in that it is project-based. In addition to class work, all WPI undergraduates must complete three projects as part of their degree requirements. The first project, the "Sufficiency," is a term paper, written under the super vision of a faculty advisor, that integrates material from five humanities courses chosen by the student. The Sufficiency is normally written during the Sophomore year.

WPI *continued on page 16*

1998 Systems Thinking and Dynamic Modeling Conference

June 28-30
New England Conference Center
University of New Hampshire
Durham, New Hampshire

The summer conference for 1998 will be held on the lovely wooded campus of UNH. Durham is just a little more than an hour north of Boston. The Center itself affords excellent meeting facilities with comfortable rooms and delicous food. Registration for the conference will start in the late fall of 1997.

Bears and System Dynamics continued from page 1

The next step was to go over the sample predator/prey model that comes with Stella. We had three books so we grouped into teams and walked through it. What I found was the students were just going through the motions without any real understanding of what was going on. Like most students, they just wanted to get "finished" rather than understand what was going on...no matter how much I badgered them to the contrary. One positive outcome from this experience...students gained an understanding of how the software worked.

I realized that I had to backtrack and help them (force them?) to wrestle with what a stock and flow were, causal loops, etc. I got on the web and downloaded some stuff from the System Dynamics in Education Project from MIT. They had a lot of resources, one of which is a copy of beginner modeling exercises. They are given a variable and they have to tell whether it is a stock or flow (some could be both) and why. There is also a series of causal loop diagrams they had to label. We went over these things and they did seem to have a pretty good understanding of the basics of stocks and flows.

The next step was to show them some generic graphs, and the generic model which produced that graph. I had gotten a series of handouts by Diana Fisher (thanks Lola) which explained how to create a model to produce a graph of linear growth, exponential growth, etc. This was something the students could relate to. So initially, what they did was to graph the behavior they wanted to model and substitute the appropriate model. This worked out well.

Once we created a couple of basic models (interest and that sort of thing), we finally got on to the topic of bears. We discussed what factors we needed to know, brainstormed what resources we might need and spent about 3 class periods searching the net for all related info. We initially had students seek non-web resources but found that the "experts" were much more comfortable talking with me than with the students.

This part was the most frustrating and enlightening. We'd get some information from the web only to have a local ranger contradict it only to have that refuted by a university wildlife professor who was contradicted by the state bear management person. The student's were quite amused to find that no one really "knew" for sure what was going on. They were very much surprised to find that much of the numbers which were being bandied about in the paper, and by both sides in our local dispute over whether to start a hunting season or not, were based on a "model" developed from a small study done around 20 years ago. The study goes as follows... based upon a small number of bears who were tagged, let go and then retrieved in a small section of Garrett County, a population was determined. Say X number of bear. At that time, there were Y number of bear/human interactions. So now, 20 years later, they say that if there are twice as many bear/human interactions, there are twice as many bear. Students were quick to point out several factors that find fault with this logic .... a new interstate was constructed since then, more people moving to remote areas, more people moving, perhaps fewer bears being reported because the "novelty" of seeing bears is less etc. This was, in my opinion, some of the best stuff they got out of the project. They felt that no one really had all the answers and that their model was as valid as the experts'.

The students attempted to create the initial model so that it matched with all of the facts we were given, such as 50% mortality for first year bears, 70% mortality by the time they were mature, between 165-200 bears in 1991 etc. The first model was created because: 1. We had numbers/facts for some of those years 2. To get an idea of what the current numbers were so that we could introduce hunting.

We were confounded by two major factors, the relocation of many bear into South Western Pennsylvania many of which made their way to Maryland and the change in hunting practices in West Virginia which caused a lesser "migration" into Maryland. We attempted to simulate that by using a time graph and making the immigration rate higher for those years when those migrations occurred. We have no numbers for that, just guesswork by the students to fit in a trend so that we got near the few numbers reported to us by our resources. I believe it introduced some artificiality to our model but with what little we had, I could see no way around it.

For me one of the most frustrating thing was the contradictory nature of facts. It was frustrating to me in that the info came at different times, usually when we were almost finished with the model based on previous information. We made several different models before the last one. It took its toll on the kids. By the time we came to the hunting component, the enthusiasm had waned considerably. I decided to leave the food source and population encroachment parts for another time.

I also am not a biology major and I felt like I was way out of my field when discussing bears. Still do. I did learn a lot though.

Another nice thing to have would have been the authoring version. It would have made it easier to create the model and would have provided us with a way for the user to supply input to make changes and see what happens.

In sum, if you are working with the type of kids I have, you have to start at a very basic level. They need to understand concepts you and I take for granted. Time spent at the beginning

Bears *continued on page 16*

Steps to Downloading Road Maps from the Internet

by Stephanie Albin and Nan Lux
MIT System Dynamics in Education Project

What is Road Maps?

Road Maps is a self-study guide to learning system dynamics. It is organized as a series of chapters, and is currently being written by the System Dynamics in Education Project (SDEP) at MIT under the direction of Professor Jay Forrester. The first seven chapters of Road Maps are available on the Internet. (Please refer to the Road Maps architecture diagram on the next page.) The Road Maps series teaches the reader how to identify different kinds of systems all around us and how to model these systems using a computer. The series can be a resource for both beginners and advanced system dynamics modelers, and requires no previous system dynamics knowledge and only basic math skills. The introduction of each chapter lists what outside reading materials and software you will need.

How to Download Road Maps

We maintain a web site where you may download each Road Maps chapter. All instructions below were written to fit Netscape software. Since most computers are different from another in some way, we apologize if these instructions do not work for you. Please email
webmasters@sysdyn.mit.edu
for more help by sending a note on EXACTLY where you ran into trouble.

Let's get started! If you already have an Adobe Acrobat Reader on your hard drive, begin here. If not or if you are having problems with your Adobe Acrobat Reader, skip to the next section below.

- Go to the SDEP home page at: http://sysdyn.mit.edu/"
- Follow the links to the Road Maps Table of Contents (or go directly there from "http://sysdyn.mit.edu/road–maps/rm–toc.html")
- Click on the link to the paper or chapter to download the document. Note that most of these are Adobe Acrobat documents (.pdf format) and you will need the Adobe Acrobat Reader to view them.

Downloading an Acrobat Reader

The Adobe Acrobat Reader is a free software program which is needed to view much of the material on our web site, including Road Maps. First, quit all other application programs you may have running.

To download an Adobe Acrobat Reader, go to the Acrobat website at "http://www.adobe.com/acrobat/" or click on the Abode Acrobat link from our web site. This link is located both on The Creative Learning Exchange and Road Maps web pages, and will take you to the Adobe home page. Click on the "Get Acrobat Reader!" button in the upper left corner of the page or on the "Adobe Acrobat Reader" link located elsewhere on the page. Then follow the two easy steps for downloading the free Adobe Acrobat Reader.

Tips on Common Problems

- Step 1, registering your software, is always a good idea. The Adobe Acrobat Reader is free and you will not be asked for money.
- PC users have one US English version to choose from. Macintosh users have two different versions to choose from. Either version is fine. It will take from 5 to 10 minutes to download. Once downloaded, either run the "ar16e30.exe" file if you have a PC, or double-click on the "install Acrobat Reader 3.0" icon if you have a Macintosh. Double-click on the "ardr30e.sit.hqx" or "ardr30e.bin" icons only if the program has not been unstuffed and there is no installation icon. Follow the on-screen instructions to install. Once successfully installed, these files may be deleted.
- With the Adobe Acrobat Reader 3.0, it is no longer necessary to configure your browser. For those with an earlier version of the Adobe Acrobat Reader experiencing the problem of Adobe Acrobat (.pdf) documents downloading as a jumble of letters in the browser window, your browser has not been correctly configured and installing the Adobe Acrobat Reader 3.0 should fix this problem.
- To save a Adobe Acrobat (.pdf) document when viewed from with-in your browser, select "Save As..." from the "File" menu of the browser. Switch the Format option to "Source" and click on "Save". When saving a document for the first time, you may be prompted to select an application. You should select the Acrobat Reader 3.0.
- If you are having installation and web browser compatibility problems, we suggest first reading the "ReadMe-Reader" text document in your Adobe Acrobat 3.0 folder before contacting us.
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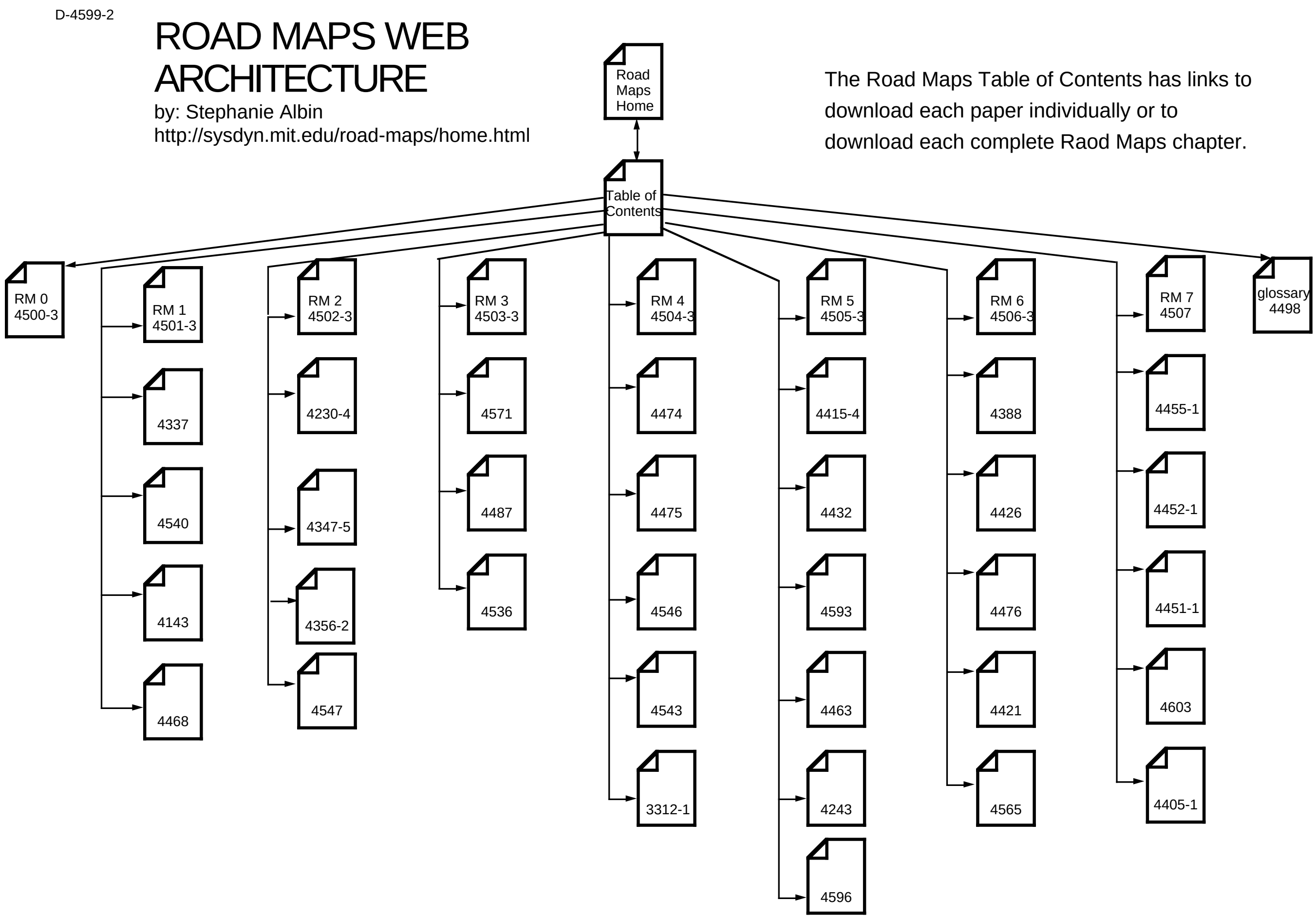

If you have any questions about downloading the browser or documents from the System Dynamics in Education Project Web Site, please feel free to email us at: "webmasters@sysdyn.mit.edu".

How to Get Materials from the Creative Learning Exchange

Many of our documents are available in three formats: on the Internet, from us on disk, and from us in hard copy. Some are available only in hard copy.

On the Internet

You can access CLE materials directly by going to the SDEP ftp site (sysdyn.mit.edu) or Web page (http://sysdyn.mit.edu/) and downloading from the CLE folder. All the materials are in Adobe Acrobat, a program which allows cross-platform viewing and printing of documents. There are two Acrobat readers available at the Web or ftp sites—one for Macs and one for Windows. (The readers are also freeware available from the Adobe server (web page: *http://www.adobe.com/*, ftp site: *ftp.adobe.com*).) If there is a problem, please e-mail the SDEP students in charge at *webmasters@sysdyn.mit.edu*.

In Disk Form Mailed from the CLE

You may order anything we have in disk format directly. The disks cost $5.00 for the first one and $3.00 for each additional one. We will fill disks to capacity. Let us know if you need the Acrobat reader disk (cost—$3.00).

In Paper Mailed from the CLE

For all school systems and teachers we charge only our copying and mailing costs. For businesses/non-educators, that cost is doubled.

You too can join the K-12 Discussion Group
(k-12sd@sysdyn.mit.edu)
To join contact Nan Lux: ***nlux@mit.edu***

New Materials Now Available from the CLE or the Web Site

SYSTEMS EDUCATION

from OTHERS

SUMMARMS ***Systems Thinking & System Dynamics in K-12 Education: A summary of existing systems.*** Mary Scheetz

During the 1995-96 school year a study, supported by The Waters Foundation, was conducted in 12 school districts around the USA that are integrating systems thinking and dynamic modeling into their programs. This paper contains the summaries of the 12 projects involved in the study. ($3.50)

CROSS CURRICULAR

from the CATALINA FOOTHILLS SCHOOL DISTRICT, TUCSON, ARIZONA

MARATHRV ***Marathon Simulation.*** Randy Valentine

Marathon1.2 simulation is designed to be used in conjunction with a worksheet and a recipe approach to step/guide students through the simulation. The simulation is used as a culminating activity for a Human Biology unit. (50¢) Model on disk.

RECYCLCJ ***System Dynamics and Your School Wide Recycling.*** Caryl Jones and David Whitaker

In this series of lessons for elementary school children, classes will look at recycling facts, school recycling behavior and changes in behavior over time. The objective is to demonstrate students' capacity to model and "make a difference" with simple "changes in behavior." ($1.00) Model on disk.

WATERPWG ***Water Pollution.*** Will Glass-Husain

Hypercard simulation to enable the students to understand how a particular industry affects the population, pollution, aquifer level, and the economy in a city. Disk available only for Macintosh. (Disk copy $5.00; Disk simulation + paper copy $6.00)

from OTHERS

RAMPQTL ***Let It Roll! An Interdisciplinary Middle School Math/Science Unit Using a STELLA Model of the Physics of Motion.*** Rob Quaden, J. Trierweiler, and D. Lyneis

In this unit, eighth graders first conduct a physics of motion laboratory experiment and then try to understand the behavior using model building, math reasoning and scientific reasoning. ($1.00) Models on disk.

ENGLISH

from the CATALINA FOOTHILLS SCHOOL DISTRICT, TUCSON, ARIZONA

GIVERB-D ***The Giver.*** Brian Bindschadler and Marveen Dickey

A simulation of the novel "The Giver" by Lois Lowry, which allows students to see that societies are created by the interplay of different variables. Students will see how changes in human behavior can affect the total society. Students will predict results and compare and analyze data based on their own choices of variables at play in a society. ($1.00) Model on disk.

STUDENRM ***Student-Generated Stock/Flow Map from Literature.*** Ron Michalak

Using behavior-over-time graphs, middle school students create a class map of the dynamics of the graphed elements in the novel "Farewell to Manzanar" by Jeanne Wakatsuki Houston and James Houston, both to facilitate a discussion of those dynamics and as preparation for an exam on the book. (50¢)

VOYAGECB ***Compare and Contrast: The Voyage of the Frog and Slake's Limbo.*** Carol Brunton

Increased understanding of "The Voyage of the Frog," by Gary Paulson and Slake's Limbo, by Felice Holman helps 6th grade Resource students develop comprehension reading skills by using System Dynamics' strategy of behavior-over-time graphing and causal loop diagraming. ($1.50)

SCIENCE

from the CATALINA FOOTHILLS SCHOOL DISTRICT, TUCSON, ARIZONA

IMMUNELK ***The Immune System.*** Lora Kulakowski

A middle school biology simulation where students control certain variables of an immune system and determine at what settings the variables must be placed for the body to ward off the invading disease. ($1.00) Models on disk.

from *OTHERS*

YEASTL-L ***GROW, GROW, GROW? A Middle School Microbiology Unit Using a STELLA Model of Yeast Population Dynamics.*** Clair Lombardo & Debra Lyneis

An introductory microbiology unit for seventh grade science students, where students learn about the basic requirements for life (food, light, water, & reproduction) in a controlled laboratory experiment and extend the experiment using a STELLA model. ($1.00) Model on disk.

SOCIAL STUDIES

from the CATALINA FOOTHILLS SCHOOL DISTRICT, TUCSON, ARIZONA

ECONINJW ***Economic Investment.*** Jeff Wadman

Suitable for grades 6-12, this simulation is designed to reinforce the concept of the three types of economic resources (capital, human, and natural) and the need for all three in production.Students are given the opportunity to manipulate the percentage of their investment in each of the three areas. The goal is to balance current needs (lifestyle) with long term benefit (growth). Students will make predictions, interpret data, and analyze results. ($1.00) Model on disk.

READINNB ***Systems Reading Project.*** Nancy Brown

Over the course of a year of Social Studies readings, students will describe and practice the skills involved in reading in the content areas, creating behavior-over-time graphs and charts for individual success. (50¢)

SYSTEM DYNAMICS

from *OTHERS*

DOWNLOAD ***Steps to Downloading Road Maps from the Internet (D-4662)*** *Stephanie Albin & Nan Lux*

Explains how to download Road Maps from the sysdyn.mit.edu website as well as how to download the Acrobat Reader software necessary for viewing/printing Road Maps and the other CLE documents. (50¢)

GRAPH4LS ***Graphical Integration Exercises Part 4: Reverse Graphical Integration (D-4603).*** Laughton Stanley

Graphically determining flow information from a stock graph. From Road Maps 7. ($1.50)

MISTAKLB ***Mistakes and Misunderstandings: Use of Generic Structures and Reality of Stocks and Flows (D-4646).*** Lucia Breierova

By examining two mistakes made in modeling a simple population of rabbits, this paper warns against the incorrect use of a generic structure and explains that stocks and flows represent real-world accumulations and changes over time. ($1.00)

RMAPS7 ***Road Maps: Part 7, A Guide to Learning System Dynamics (D-4506).*** System Dynamics In Education Project

Part 7 in a series of 7. Includes a) Unexpected Behaviors in Higher-Order Positive Feedback Loops (Aaron C. Ashford) (D-4455-1) *A discussion of the unstable behavior modes possible in positive feedback loops*; b) Mistakes and Misunderstandings: Examining Dimensional Inconsistency (Michael Shane Gary) (D-4452-1) *An examination of dimensional inconsistency and the normal mistakes which occur in trying to define dimensions within system dynamics modeling*; c) Modeling Exercises, Section 2 (Joseph Whelan) (D-4451-1) *Two separate modeling exercises and their solutions*; d) Graphical Integration Exercises Part Four: Reverse Graphical Integration (Laughton Stanley) (D-4603) *Graphically determining flow information from a stock graph*; e) System Dynamics, Systems Thinking, and Soft OR (Jay W. Forrester) (D-4405-1) *A discussion of systems thinking and soft operations research as related to system dynamics.* ($10.00 [$20 non-educator price] in hard copy or $5.00 [$10.00 non-educator price] for a disk.)

SOFTORJF ***System Dynamics, Systems Thinking, and Soft OR (D-4405-1).*** Jay W. Forrester

A discussion of systems thinking and soft operations research as related to system dynamics. From Road Maps 7. ($1.00)

UNEXPEAA ***Unexpected Behaviors in Higher-Order Positive Feedback Loops Loops (D-4455-1).*** Aaron C. Ashford

A discussion of the unstable behavior modes possible in positive feedback loops. From Road Maps 7. ($1.50)

System Dynamics at Worcester Polytechnic Institute, Worcester, MA

continued from page 10

The second project, the "Interactive Qualifying Project" or "IQP," is an interdisciplinary junior-year thesis in which students, under faculty supervision, investigate some aspect of the interaction of technology and society. Often, the IQP is done in teams, off campus at one of WPI's many project centers located in the United States and abroad (e.g., Washington, DC, Venice Italy, London, England). Occasionally, the IQP is funded by either a public sector or private sector organization.

The third project, the "Major Qualifying Project" or "MQP," is a senior-year thesis for which students, under faculty supervision, conduct original research in their major area of study. As with the IQP, the MQP is often done in teams, and frequently for a sponsoring organization.

WPI's "program" in system dynamics is not a "major" in system dynamics (although, if enough student interest arises, one could be created). Rather, a student can take *any* major offered by the Institute and, as part of his or her degree requirements, take a two-course sequence in system dynamics followed by a system dynamics-based IQP (completed on or off campus, in the US or abroad). WPI is, to my knowledge, the only institution in the United States (and probably in the world) that offers such a program *at the undergradate level*. A student can also put together a minor in social science and modeling that consists of the system dynamics courses, the SD-based IQP, and courses that complement the SD material (e.g., differential equations, control theory, programming, management, psychology).

In terms of majors, WPI offers undergraduate degrees in the natural, mathematical, engineering and social sciences, as well as in the humanities. Social science majors include economics, economics & technology, environmental policy & development, and society, technology & policy. So cial science majors interested in system dynamics can do a system dynamics based MQP.

WPI students who have completed the system dynamics program have gone on to do graduate work in system dynamics at MIT and the University of Bergen (Norway) and/or have landed system dynamics jobs in industry.

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Bears and System Dynamics

continued from page 11

pays off. Much of it was massed practice stuff till they got the concepts down. I also think the generic graphs/models is a good thing to use. It gives them their own "map", and it makes them think about what the graph will look like "before" they do the model which causes them to think about what the variables are and how they interact.

I have included two models, one is the bear population without hunting and the other includes hunting. A more formal presentation is available at http://husky.northern-hs.ga.k12.md.us

The models are available from the web or the CLE.

Tom
tbulka@husky.northern-hs.ga.k12.md.us

❖

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