the Creative Learning EXCHANGE

Volume 13, Number 1 - Winter 2004

SYSTEMIC PLANNING

By Ralph Brauer, John Heinbokel, and Jeff Potash

It was Lees Stuntz who started it all by broaching a revolutionary idea—in Concord, Massachusetts no less. It was a drizzly summer day not far from the hotel where Thoreau once ruminated the Mexican War, within walking distance of the homes of Emerson and the Alcotts, and down the road from Author's Ridge where Emerson lies under a white quartz boulder and Thoreau's simple marker is often surrounded by wilting flowers and odd bits of wood. Further down the same road lies the "rude bridge" where the shot was "heard round the world" and an intersection that leads to Walden Pond.

As we packed boxes at the end of that year's CLE conference, Lees proposed that we needed a systemic understanding of how school systems functioned. At the time she made this suggestion, no one had built a System Dynamics model of a school system—most educators had never heard of System Dynamics and only few of them had any inkling of what systems thinking involved. The buzz-word at the time was "systemic reform," but there was very little that was systemic about most of these efforts. Those of us in education had less understanding of the interrelationships of a school system than we did of the inner workings of the atom.

Curiously, the atmosphere in education was not unlike that in America during the years leading up to the events that made Concord a household word for revolution: a great deal of activity and innovation along with a growing frustration. At the conference the air was full of talk about research studies of various new programs. There was a healthy spirit of innovation that had spawned a wealth of programs in classrooms across the country. What we lacked was any clear sense of how all these efforts fit together. What was especially frustrating was that reformers had spawned successful innovations, only to find they could not replicate them at other sites.

We seemed to have more questions than answers. Should a district hire a few high salaried experienced teachers or a lot of lower salaried novice teachers? Option two might lower class sizes but would it lead to an increase in student performance? How much more support would these inexperienced teachers require than their more experienced colleagues? How important were advanced degrees for teachers? What was the ideal ratio of administrators to teachers and students? Would material support efforts such as adding more computers have an impact on the number of teachers? On performance? Most of all there was the "big" question nagging us all, one which had inspired not a few skirmishes reminiscent of what had occurred so long ago in Concord: How could we be spending more money than ever before and still have large numbers of students who were not performing well? What did it take to improve student performance? Where are the maximal leverage points? Are these the same for all systems?

Systemic Planning *continued on page 3*

ECONOMICS AND SYSTEM DYNAMICS FOR YOUNG STUDENTS

Debra Lyneis, Creative Learning Exchange
Rob Quaden and Alan Ticotsky, Carlisle Public Schools
Presented at the 2003 International System Dynamics Society Conference

ABSTRACT: *Today's students need an understanding of economics and system dynamics to participate effectively and fully in our complex global economy, but very few K-12 schools teach either discipline. In Carlisle, Massachusetts teachers have developed several basic economics lessons using system dynamics for students in fourth to eighth grade. This paper will describe those lessons and how student response to system dynamics instruction has spurred the need to expand the system dynamics/economics curriculum.*

INTRODUCTION

Jay Forrester has often said that system dynamics could be the vehicle for integrating effective and desperately needed economic education into the kindergarten through twelfth grade (K-12) curriculum. Students need a sound understanding of economics in order to thrive in a global economy, yet very few schools offer economic education to K-12 students, and fewer still approach it

Economics and SD *continued on page 6*

Updates…

Waters Foundation, Portland, OR

One of the Waters Foundation K-12 Educational Partnership sites is based in Portland Public Schools in Portland, Oregon. The site serves over 100 schools in the Portland district as well as schools in surrounding districts. Through workshops, coaching, and training, the project mentoring team interacts on a regular basis with educators from more than 50 area schools.

One vehicle for interaction is the Waters Foundation Collaborative Action Research Process. An interesting topic being studied by one of the research teams is the development of the "habits of a systems thinker" in high school and middle school students. This work was motivated by the correlation between the habits of systems thinking and the Habits of Mind work that was developed by Art Costa and Bena Kallick.

In an effort to serve large numbers of schools in an effective manner, 30–hour courses in systems thinking and dynamic modeling are offered for Portland State University credit. Those courses include Level I, Level II, Systems Thinking and Habits of Mind, and Systems Thinking and Leadership. The Leadership course is based on the Donella Meadows article "Dancing With Systems," and is offered to all educators involved in leadership and school improvement.

The work of this Waters Foundation project has grown significantly in the past 5 years. Meeting the needs of educators who work in a large, metropolitan area has required an analysis of the potential leverage and long term sustainability of actions. At present, the educators involved are enthusiastic about continued refinement and expansion of systems thinking and dynamic modeling in the Portland K-12 arena.

EDITORIAL

As I write this, New England is in the deepest freeze we have had in 20 plus years. Our whole perspective has warped—25 degrees looks positively balmy! Even though winter has us in its grip, our concentration here at the CLE is focused on the conference to be held at Skamania Lodge near Portland, Oregon, June 30-July 2. Not only do we have a stellar pair of Keynote speakers, but we expect to have the opportunity to visit with interested, and interesting, colleagues who are passionately interested in K-12 education, both from our K-12 schools and from the system dynamics community. Once more, we will be lucky enough to have the progenitor of the field of system dynamics as well as the strongest proponent of its use in K-12 education, Jay Forrester, with us to share his ideas.

Our lead article in this issue is a description of a model being used in Minnesota and elsewhere to help administrators grasp the systemic effects of educational and financial policies. One of the workshops at the conference will be a training session on the software for those who are conversant with modeling. This is only one of many interesting workshops and sessions that will be held. We look forward to seeing old friends and meeting new ones at Skamania in June.

Take care,
Lees (stuntzln@clexchange.org)

Waters Foundation, Tucson Unified School District

The group at Carson Middle School is concentrating on training. By the end of the year, over 90% of the staff at Carson will have gone through a one day training with Tracy Benson and their mentor, Cheryl Dow. (Cheryl is still in training and assists Tracy.) The principal, Mary Quinnan, is also utilizing various systems tools during staff meetings, which helps to reinforce the use and effectiveness of systems tools. Staff work through relevant school and classroom problems using the Ladder of Inference, BOTGs, stock/flow diagrams, and systems archetypes like the "fixes that backfire." They have examined issues like the district and school retention process, the effects of new reading strategies on levels of student engagement, and the quality of staff conversations during problem-solving sessions. On a weekly basis, Mary also reviews lesson plans and makes it a point to visit all classes that specifically utilize systems strategies. It is so great to see such wonderful administrative support!

Greater Tucson folks have also trained the whole staff at Los Amigos Elementary School in the Sunnyside School District on BOTGs as a nonlinguistic instructional strategy (see Robert Marzano's *Classroom Instruction that Works).* Each teacher was involved with mini lessons during the training and made plans to incorporate the use of BOTGs in their classrooms. Two weeks after the initial introduction, the faculty met as a whole group to share student BOTG samples, debrief the strategy, and make future plans for both training and classroom applications.

***Updates** continued on page 14*

Systemic Planning continued from page 1

Lees started us on a journey that has led to our creating a System Dynamic's-based process some of you may recall seeing at the last CLE conference, almost two years ago. Because the model was in its draft stages, we wanted to use the conference as an opportunity to hear what people thought about our efforts. One evening after that presentation, the three of us [*ed. note*: Ralph Brauer, Jeff Potash, John Heinbokel] took a drive to York Beach and walked in the sand not far from the Nubble lighthouse. We spent the evening pondering suggestions from Barry Richmond, George Richardson, Jay Forrester, Peter Senge, Lees, and others. All had been more than gracious with their time and ideas, reinforcing the value of a conference that brings together so many different people, from the founder of the discipline to researchers, educators, practitioners, and others.

Perhaps the biggest change over the last 18 months has been our reconceptualizing the project as a process rather than a tool. When we presented the model at the last CLE conference, we thought of it as a software tool that would enable K-12 educators to better understand their systems. As we have used the model in various school districts, we have come instead to see it as the center of a systemic planning process. The difference is not a trivial one. If seen as software, the model could possibly end up in a locked office with a single user punching a few keys and manipulating a mouse with the hope the model would produce "an answer." If seen as a part of a systemic process, the model inevitably becomes the facilitator for group discussion and analysis, the results of which are deeper understandings of the tradeoffs of possible alternatives, and, most important, better questions about the whys of their situation.

In the course of improving the process we have been fortunate to have had the assistance of a team of educators and researchers who have helped us to better understand the questions raised by the model building process. Because creating a model building team is perhaps the most important part of the process, we wanted ours to include classroom practitioners as well as university researchers. Team members included: Superintendent Jim Oraskovich and teachers Jim Boos and Jim Minerich from the Pequot Lakes, Minnesota school district; Betsy Chase, an administrator from the Chaska, Minnesota school district; Mark Davison, head of Minnesota's Office of Educational Accountabilty, and Kyla Wahlstrom, Assistant Director of the University of Minnesota Center for Applied Research and Educational Improvement. We also have received funds from the Bush and Blandin Foundations and the state of Minnesota to aid our efforts, although, as with many grants, the time and effort made by team members have far-exceeded the level of funding.

As those of you who have built models know, the choice of what to model is a critical one, driving the key stocks and flows that form the superstructure that anchors everything else, much like the steel framing of a skyscraper. For us, that choice was an easy one: we wanted to focus on the one issue that has been plaguing education since *A Nation At Risk*: student performance.

We chose to construct the model such that the definition of performance would be flexible enough to accommodate a variety of goals and assessment measures. We did not want to be caught in the trap of focusing only on test scores. All of us believed that the present emphasis on using standardized tests to judge the performance of schools, districts and teachers is misguided and dangerous. Most schools have a wealth of performance data, some of which is published in local newspapers and others sent to state and federal officials as part of various reporting requirements. Within these reams of spreadsheets, what is often missing is a clear and useful understanding of the feedbacks (systemic complexity) that underlie and control those correlations. Based on several daylong meetings of our team, we built a very basic outline model that we continued to refine over the next few years. We call it an outline model, in that while it functions as a System Dynamics model, it is not intended to be run, but rather is a summary, in model form, of our key ideas. That basic model is shown on page 4.

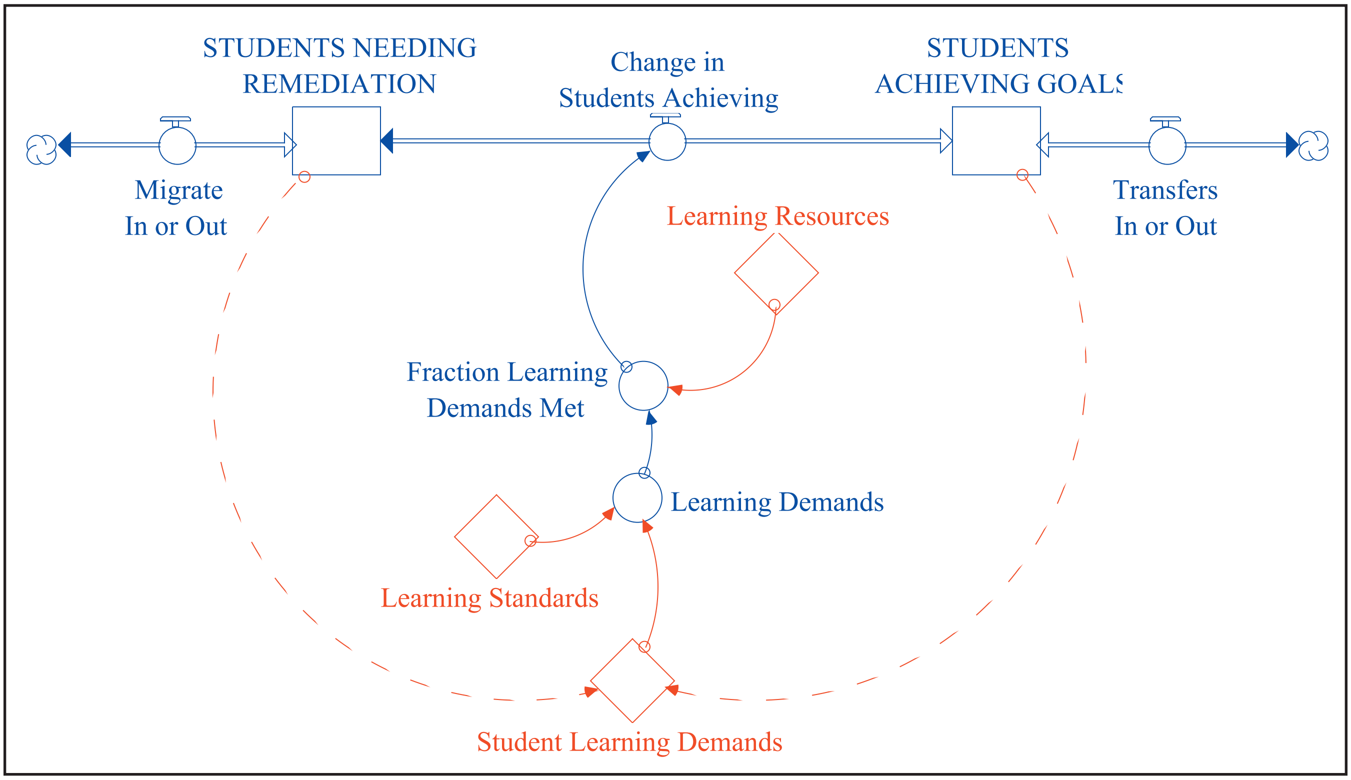
The story behind the basic model is a simple, but powerful one: students are either achieving or still trying to master user-defined goals which can be attendance, discipline, graduation rates, extracurricular participation, as well as multiple standardized tests and assessments. The STUDENTS NEEDING REMEDIATION stock can include students who have not yet achieved goals, as well as "backsliders" who may have initially mastered them, but, without adequate reinforcement, have regressed. The student stocks have inflows and outflows for enrollment changes.

The key part of this outline model is obviously the flow governing the movement of students between the two main stocks. Notice this is a biflow, representing a concept familiar to every teacher, administrator, student and parent: students can move in either direction. This biflow is affected by the three process diamonds, which represent dozens of interrelated sub-models and equations. To understand these and their accompanying feedbacks, you need to know about the "currency" of the model. In early drafts, we had used money, following the conventional wisdom of asking, "how much does it cost?" When we began a major rebuild, Mark Davison suggested we should build the model using "time" instead of money as the focus.

This was a radical insight, the implications of which we are still just beginning to understand. To the teachers and administrators who were working with us on the project, the insight seemed obvious: students take different amounts of time to master something. Teachers,

Systemic Planning *continued on page 4*

Systemic Planning continued from page 3



based on skill and training, take different amounts of time to teach those students. We factored time into the model as measures we called demand and resource units—which represent the time demands presented by each individual student and the time the system has to meets those demands. The Student Learning Demand process diamond includes sub-models of academic demand (what is their intellectual ability to master the goal) and behavioral demand. As we all know, a student can be a genius but also a huge, time-consuming behavior problem. Behavior proved interesting, for we found there was very little research or data on how behavior influenced learning, even though everyone talks about it. We ended up creating a rubric of our own to define the various levels of behavior.

The basic functioning of the system revolves around how much demand the students collectively represent and what resources are available to meet that demand. In essence, the model is a supply-demand equation, albeit a very complex and powerful one. The Learning Resources process diamond includes sub-models of all the resources of the system: teachers, administrators, and support (which includes everything from staff, aides, and paraprofessionals to computers and classroom supplies). All of these are valued in terms of time: master teachers can usually teach a skill to a class in less time than a novice, not only because they have more experience and training with the subject matter, but also because they have more experience and training with classroom resources and, of course, with classroom management, including discipline. The rest of the system helps to enhance or diminish this "efficiency."

The third series of sub-models represents the Learning Standards for the achievement goals, standards that include school and district expectations, the expectations of the community, and whatever standards and expectations state and federal governments impose. The gaps between these and actual performance, and between themselves, are, as we know, drivers of powerful feedbacks that control the dynamics of the system. If student performance is below state or federal expectations, No Child Left Behind and similar legislation may impose a penalty on the district. If performance is below community expectations, it can result in lower funding levels, teachers bailing out of the system, changes in administration, and enrollment shifts.

As the old saying goes, "The devil is in the details." To minimize the potential for deviltry, the larger model built on this basic structure underwent numerous validity tests. Minnesota districts entered data from past years, and we then ran the model, using the policy decisions they had made, to see if the model results conformed with what had happened. We subjected the model to a statistical technique called path analysis to confirm the correlations between various variables and sub-models. This was especially crucial since it helped to confirm the relative strength of various correlations.

As those of you who have used models in the classroom know, the actual physical model should be part of a good lesson plan. Although we were gratified that the model passed all the above tests, we knew we needed to develop a systemic process that facilitated maximal use of the model. Crucial to this development were funds from the Blandin Foundation, which were awarded to us to incorporate a goal-setting process facilitated by the model into its educational leadership program, which has taken place over the summers of 2002-2003. Blandin is a Minnesota-based foundation tightly focused on the economic viability of rural Minnesota communities, as part of its mission to help strengthen rural Minnesota and its home city of Grand Rapids. Since its inception in 1986, the Blandin Community Leadership Program has received national and international acclaim for training 3,800 leaders in 244 Minnesota communities.

The Blandin experience taught us how to introduce System Dynamics to audiences who had little familiarity even with systems thinking. We also created a variety of facilitation techniques and tools, many of them borrowed from a successful strategic planning process used by the Transforming Schools Consortium. These included materials on mental models, goal setting, and assessing alternatives. We even created a series of "cheat sheets" that allowed users to run the model in small groups.

By now you can probably see that the assumptions behind the process radically reframe much of the policy discussion about schools. It is especially relevant to answering the major question that plagues us today: why are some schools with high per pupil expenditures doing well and others are not? Why are schools spending less money doing well while others are in trouble? Currently the debate focuses on dollars and test scores without any attention paid to the issue of supply of AND demand for resources.

We have come to believe that the lens of student demand is an especially powerful way for everyone in education to reevaluate the ways they are thinking about school performance. Much as Emerson and the Concord Transcendentalists challenged their generation to adopt a new perspective for seeing and experiencing their world, so we need to better understand the interconnected power exercised through student demand upon the world of education. Policy decisions that penalize districts with low scores may set into motion a variety of unintended consequences.

Examples include the flight of high performing students to other schools, thereby leading to further declines in overall performance. Alternatively, penalties may undermine morale in administrative and teaching staffs, thereby triggering departures and reducing overall capacity. Given, in both illustrations, that the full consequences of the penalty may in fact not be evident until long after the decision has been rendered, it is imperative that the feedback implications be fully understood before such decisions for improving student performance are made. So, too, it is equally important to factor current demand levels into any decision. A school with low test scores may in fact be doing quite well with the limited resources it has. To call such a district "low-performing" may not only be inaccurate but also dangerous.

A few examples from work we have been doing with schools in the last few years show how this reframing can provide significant insights and raise better questions. In one district where we ran the historical analysis, teachers and administrators had been puzzled by why test scores had continued to stay high, even though their budgets had been decreasing. What the process told us was that their performance largely stemmed from a development program they had put in place several years ago, yet that staff development program was under consideration as a possible budget cut. Now they are pondering the role of staff development in their system and how it relates to other elements. In another district, teachers in an elementary school explored policy options for how to cope with increasing enrollment and flat or decreasing budgets. At the end of the day, one teacher exclaimed that process was the only one she knew that could have brought everyone together without rancor. In both cases, the most powerful result was the degree of inclusive and productively open dialog that the process produced. Perhaps most striking in this regard is the Blandin program, where teams are now asking questions about which goals have the most promise and why.

In all these instances, it was not so much the particular decision that mattered, but the larger insights the process provided. In the district with the staff development process, their Director of Research, Evaluation and Assessment is now trying to get teachers and administrators to think of their system in terms of demand units. In the elementary school they have seen the value of System Dynamics in teasing out mental models and facilitating discussions that move from who to why. In the Blandin program, perhaps the most gratifying evaluation came from a Native American district, which said that the process was the first one they had seen that was congruent with the decision-making traditions of their culture. They felt that the process was nonjudgmental, that it not only allowed for, but benefited from, the input of all, and more closely mirrored a world view that is circular rather than linear.

As much as anything, this response confirmed for us the power of the process to engage a diverse group of audiences. In the Blandin training, teams included teachers, school administrators, staff members, school board members and community leaders. We have also worked with city, suburban, and rural schools, as well as the tribal school mentioned above. System Dynamics appears to have a unique ability to engage diverse participants and to move people away from who to why, from blaming to analysis.

While there has been much pressure on us to regress to seeing the model as a decision-making tool—including an offer from a software vendor shortly after our presentation—we have firmly re-

Systemic Planning *continued on page 14*

Economics and System Dynamics continued from page 1

through a system dynamics perspective. Although there are some successful lessons in the works, a comprehensive K-12 economics curriculum based on system dynamics is still an opportunity waiting to be developed.

Students and teachers at the Carlisle Public Schools in Carlisle, Massachusetts have experimented with a few system dynamics lessons in basic economic education. This paper will describe those lessons, how they were developed, and how the need for more such lessons has been evolving in recent years. Economics has been a late-comer to the system dynamics curriculum in Carlisle. Only now is Forrester's advice beginning to sink in, prompted, as it turns out, by the very questions that students raise as they apply system dynamics to other areas of their study.

System Dynamics and Economics in Carlisle

Carlisle is a small suburban Boston school district with a total enrollment of 843 students in kindergarten through eighth grade. In 1994, a middle school math teacher and a middle school science teacher first experimented with system dynamics in their classes. Since then, system dynamics has slowly grown in Carlisle as a useful approach and set of tools to enhance the regular curriculum. This growth has been nurtured and nudged by a supportive administration, school board and community. Also, the Waters Foundation has generously provided funding for two systems mentors, Rob Quaden and Alan Ticotsky, teachers who help their colleagues learn and implement system dynamics in their classes.

In the early years, because there were few examples to follow or completed lessons to use, the mentors plied their system dynamics ideas and developed lessons with whichever teachers seemed to show an interest – usually math and science teachers, often in the middle school. These were the "early adopters," tolerant of the uncertainty that accompanies innovation. Gradually, with more training opportunities and encouragement provided by the administration, the circle of interested teachers expanded to include literature teaching and many elementary grade lessons. This year, now that the support and training structures have been laid, *every* teacher in the school is required to implement at least one system dynamics lesson each year as part of his/her performance evaluation. Because system dynamics had proven its worth for students, Superintendent Davida Fox-Melanson believed that the time had come to take this next step and bridge the gap to include the larger majority of teachers who are reluctant to embrace innovation at first. We do this because we believe that students will need system dynamics skills to deal with dynamic complexity.

Meanwhile, mentors Quaden and Ticotsky have been developing and assembling a growing list of successful lessons and gradually pulling together a sequential K-8 system dynamics curriculum. Throughout, system dynamics is never taught as a course on its own. It is infused into the regular curriculum as a way to make learning better for students. It is a set of tools in a learner-centered experiential approach to education.

Economics, however, has not been prominent in this curriculum, even though we have long had the sense, and Forrester's advice, that it should. There may be several explanations.

- Math and science teachers were the first to be drawn naturally to system dynamics. They were more comfortable with the equations and technology, they already used experiments in their teaching, and they were looking for "real" computer applications for their students. Also, system dynamics models of physical systems seemed easier to grasp at first. In the early years, the Carlisle mentors were busy with math and science applications.

- Unlike math and science, economics is not one of the core subjects taught in K-12 schools. There is not a ready curriculum to be enhanced with the use of system dynamics tools. Indeed, teachers, who are themselves products of the same system, do not have much background in economics unless they have sought it out in upper level elective courses. To introduce an economics strand in K-12 education would be to start from scratch (a perfect opportunity, according to Forrester.)

- Because economics is not part of the core curriculum, it is not measured in the high-stakes standardized tests which drive (and constrain) so much of K-12 instruction. School districts, and teachers, are forced to dwell on the tested subject matter, leaving little room for anything else. Schools, like Carlisle, where students already perform well on statewide tests, have some liberty to tinker with the curriculum, but the pressure is still there and time is precious.

- Social studies *is* a core subject. Economics could reasonably fall there. However, the traditional emphasis (and thus the standardized testing) has been on history and political science. Even so, system dynamics has made slower headway in K-12 social studies, partly because soft systems seem more difficult to model at first and because social studies teachers are not as accustomed to using models and computers in their teaching. In time, these will change. In Carlisle, we have had some good social studies lessons and we know that we need to do more if we are going to give students the essential tools and perspective to deal with the complex social issues facing them. Economics may just be our entrée.

The goal in Carlisle is not to teach a K-8 Economics course based on delivering the content of a typical high school Economics textbook. Rather it is to help students gain an understanding of basic economic concepts as they apply to their current curriculum and their daily lives. System dynamics forces education to be interdisciplinary. As students use system dynamics as a tool, their own questions lead them into areas of exploration beyond the usual curriculum boundaries. Economic questions are arising more frequently in social studies and science lessons, indicating a need to introduce more economic education into the K-8 curriculum. Several of the Carlisle economics lessons below grew from this need.

Another place for basic economic lessons is in the teaching of system dynamics itself. In order to use system dynamics, students need to learn about stocks and flows, but system dynamics skills are not taught in isolation as a separate course. Lessons in saving and spending money, interest rates, credit and other money management issues provide a good context for learning basic system dynamics concepts along with economic concepts. (Students then transfer the same structures to other areas of study. That way, math, system dynamics and other formerly distinct subjects are woven together.) The series of bank balance lessons below began as system dynamics lessons through which students became engaged in thinking about economic decision-making.

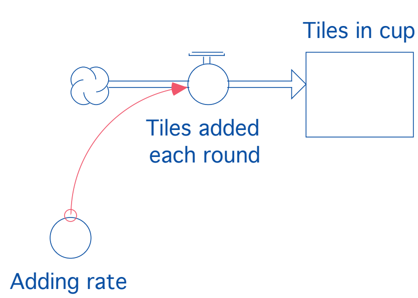
In Carlisle, system dynamics is built into the curriculum for all students across the grades and subject areas. It is not only for gifted students or students who are interested in math. This is not a problem. Teachers are often pleasantly surprised at the enthusiasm and depth of understanding that even young students can achieve across a class. (Sometimes students who have had difficulty with other approaches find a new chance for success with the systems approach.) If there is any constraint, it is that some teachers are more reluctant to plunge into unfamiliar areas than their students are.

BANK BALANCE LESSON, SIXTH GRADE

One obvious and useful system dynamics application to the study of basic economics is the modeling of bank balances. Carlisle students do bank balance lessons in fourth, sixth and eighth grade. With increasing complexity and independence they build basic system dynamics models to understand how money accumulates with simple and compounding interest. They learn about deposits and withdrawals as flows into and out of their stocks of money. They are introduced to the ordinary business of living.

Several years ago, Rob Quaden began teaching students to build bank balance models in sixth grade math classes (eleven year olds). Students always have difficulty understanding percentage, interest rates, and the formula: *Interest = Principal x Rate x Time*. The modeling lesson was an attempt to help students grasp the concept more intuitively. It was also a way to let students "play" with the idea on the computer while also building their system dynamics skills.

Students begin with a constant inflow to the stock. Before they can consider the concept using numbers and money, however, they begin with a very concrete tactile activity using little tiles in paper cups. For example, to figure out how many tiles would accumulate in the cup over a certain time at a certain rate, they physically place the tiles in the cup, count them and record their findings on a table of values.



Next, they draw stock/flow diagrams and in teams build STELLA models of the tile problems, producing straight line graphs. Only after they can see that the computer model produces their same table of values are they ready to start thinking about money, one more level of abstraction. It is important not to skip this step. Even young students today are computer savvy. They can click and drag and fiddle with numbers in order to make their graphs "work." The point of this math lesson, however, is to help them understand exactly what the computer is *doing* and, beyond that, to understand exactly how simple and compound interest *work*. System dynamics provides the chance to move beyond mindless computer games and the rote application of formulas, *if* students are given the means to understand just what they are doing.

Students are then given a list of piggy bank problems. With discussion, they observe that the structure of the tile problem is just like that of the money problems. They change the labels on their tile models and get to work. This is fun.

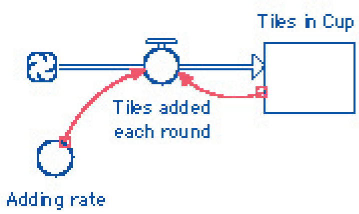
- John has $8.75 in his piggy bank. He adds $1.75 a week. How much money does John have after 4 weeks? When will John have $42.00?
- Mike has saved $78.00 and saves $4.00 per week. Melanie has saved $124.00 and spends $3.00 per week. When will Mike and Melanie have the same amount of money?

(By the sixth grade, Carlisle students are already familiar with basic system dynamics and the mechanics of STELLA. Students are introduced to stocks, flows, and graphing in the primary grades. See "The In and Out Game," by Ticotsky, Quaden and Lyneis, "Graphing the Friendship Game," by Ticotsky and Lyneis, and "The Mammoth Game," by Stamell, Ticotsky, Quaden and Lyneis. In the fifth grade, they use those skills in curriculum applications like "It's Cool" a science lesson by Quaden, Ticotsky and Lyneis, and "Tuck Everlasting" a literature lesson by Platt, Quaden and Lyneis, all available at the Creative Learning Exchange website: www.clexchange.org.)

Economics and SD *continued on page 8*

Economics and System Dynamics continued from page 7

Once students understand constant flows, they are ready for compounding flows, but again, they still need the concrete activity before they are ready to leap to interest rates at the bank. Once again they count tiles into paper cups, but this time the number added depends on the number of tiles already in the cup. Starting with 8 tiles in the cup, they are given the "rule" to "add one half as many each time," recording their results on a table of values. As 8 tiles become 12, then 18, then 27… students notice a difference in the accumulations from the earlier constant flow tables.



As before, students draw stock/flow diagrams of the tile activity, this time with a good discussion on the new feedback loop. They build their own STELLA models of the tile problem in teams and follow that with problems involving money. This is a difficult step, however, because it takes an extended explanation of percents and interest rates to make clear their connection to the "add half as many" rule in the tile problem. Using their own bank balance models, students solve problems such as:

- Elena deposits $640 in a bank account. After each year, the bank adds interest to her account at a rate of 4%. Build a model of this situation and answer the following questions:
  - How much money will be in Elena's account after one year?
  - How much will she have after five years?
  - How long will it take for her money to double in value?
- Jim has a credit card bill of $246.00. The credit card company offers to let him wait six months before paying back any money, but they will add 1.5% to his debt each month. If Jim agrees to the deal, how much will he owe after the six months are up?

Many good questions arise out of this lesson:

- What is the difference between the graphs of the constant flow and the linear flow (where the stock is multiplied by a constant)?
- Which yields you more money in the end? Why? Which would you rather have?
- Why is the line curved when the bank balance accumulates interest? Why is the other line straight?
- Why does the curve have the same shape no matter how much money you have or what interest rate you use?
- How long does it take your money to double in different examples?
- What is "2*e* + 115" on the vertical scale? Students *always* test the limits of their models and are so pleased at how fast they can become gazillionaires at 100% and higher interest rates! Discussions ensue about whether this can actually happen. Students are also introduced to scientific notation in a practical application.
- How many years does it take to accumulate a certain amount of money at one interest rate? At another interest rate? (Saving for college, for example.)
- What interest rate do you need in order to accumulate a certain amount of money in a set time? What interest rates are reasonable returns these days?

Sixth graders can get their minds around all of these questions, and they love doing so. The bank balance lesson is intrinsically appealing to them because it involves playing with computers and money. Meanwhile, they are learning a great deal of math and basic preliminary economics.

BANK BALANCE LESSON, FOURTH GRADE

Two years ago fourth grade teacher Bill Gale saw a good place for system dynamics in his curriculum. He had participated in system dynamics training sessions held in Carlisle by the mentors, and he had attended an energizing High Performance Systems workshop for businesspeople and teachers, led by the late Barry Richmond. Because Gale had come to teaching from a career in the computer industry, he was comfortable with the approach and eager to use it with his students. He decided to build bank balance models with his students.

Gale definitely pushed the standard for Carlisle. Until then, we had thought that only sixth graders were ready to build models and understand bank balances with interest. Gale showed that younger students (9 year olds) were ready too.

The first time Gale tried the lesson two years ago, he gave his students some preliminary classroom instruction on the mechanics of STELLA and the concepts of simple and compound interest. When he loosed the students onto the computers in teams, they did surprisingly well. They were able to solve piggy bank problems and interest problems, accumulate enormous amounts of money and have fun. Yet, there lingered among the teachers some doubt about the real depth of the students' understanding.

Last year, with the help of the systems mentors, Gale used the concrete tile-counting activities with his students to lay the groundwork for the computer modeling. This worked much better. Barry Richmond was in Carlisle on the day that the students built their STELLA models. He got right in there and coached these little kids with the same enthusiasm and respect he would offer to much more sophisticated modelers. He was impressed with the students; they were awed with him.

This year (2002-3), Gale has further refined the lesson. Students did the tile activity and piggy bank problems in the early fall. They will do the compounding interest problems in the spring after they have had more background in math and system dynamics. Gale will continue to fine-tune the lesson. Sharper students have always grasped it easily, but Gale wants to make the concepts accessible to every student in the class by weaving it into the curriculum.

Fourth graders are able to answer many of the questions put to the sixth graders, but at a simpler level. They require more time to manipulate the tiles and record their results. They also need more help with using STELLA because this is their first exposure to building their own models. More of the questions directed to them focus on honing graph-reading skills: How much money do you have at a certain time? How long does it take to save a certain amount? If they can get all this background in fourth grade, they will eventually be able to go further in later grades.

EIGHTH GRADE LESSONS

By the eighth grade, students have had considerable exposure to system dynamics. They have worked on the math underpinnings, the concepts of feedback loops and stocks and flows, and the mechanics of STELLA. They have applied these tools to problems in various areas of the curriculum, and they are beginning to see the transferability of structures in different applications. There are several established system dynamics lessons built into the eighth grade curriculum, but there are also times when issues pop up and system dynamics tools seem to provide the best way to address them. Again, economics is not a core subject. There is not yet an explicit thread of economics lessons in the curriculum. There are, however, system dynamics lessons that include economic concepts and raise economic questions. As these lessons accumulate, it becomes clearer that we need to focus more on economics in our curriculum.

Bank Balance Lessons

Building on their earlier experience, eighth graders revisit the bank balance problem. This time they do not need the concrete tile activity and they are ready for more sophisticated real-world problems. The bank balance lesson takes three different forms in eighth grade.

Exponential Growth

One major focus of the bank balance math lesson at the eighth grade level is the concept of exponential growth/decay. Now that students understand how it works with money, they are able to recognize the same reinforcing structure in other settings. In other areas of the curriculum, they study population growth in humans and fish, bacterial growth, and the spread of epidemics using models. The bank balance structure ties into all of the other models of exponential growth. Exponential growth is the math lesson; system dynamics is the tool which helps students understand how it works and recognize it in the systems around them.

Understanding *dt*

The bank balance problem is used to explain how *dt* works. This is essentially a system dynamics lesson. Students know that fiddling with *dt* changes their model output, but they have no idea why. (For young students, we just give them the *dt* value and tell them not to change it. Often it is set at 1, because it is confusing and disconcerting for young students to think about half a person or half a mammoth.)

To experiment with solution intervals, students do pencil simulation (no computer) to compute and graph interest that is paid once a year over several years (say, 10%/yr. on an initial $100 deposit, for easy calculations.) Using the stock equation as their guide, they compute the value of the interest ($10 for the first year), add it to the bank balance and go on to compute next year's interest, and so on.

Balance(now) = Balance(last computed) + (Deposits) x dt
Deposits = Balance x Interest Rate

In this case, *dt,* the solution interval, represents the compounding time. When interest is compounded annually, its value is 1. Next students compute the value of the bank balance over several years when interest is compounded twice yearly. The deposits are multiplied by .5 because the bank pays only half of the interest over half a year. Students repeat the computations for quarterly interest, observing the difference in the accumulations and in the approaching smoothness of the graph lines as the intervals grow smaller.

Finally, students try the same simulations on their computer models of bank balances. They experiment with different values of *dt* representing annual, quarterly, and daily compounding. They compare annual percentage yields and discuss the diminishing returns of smaller and smaller compounding times.

Technically, of course, *dt* is not linked to any real world value. It is an artifact, a simulation solution interval. However, it helps students understand how *dt* works if they can play with a more concrete example first. The familiar bank balance model makes the purpose of *dt* more accessible to them. Meanwhile, they are learning a useful lesson about banking their own money.

Constant and Compounding Inflows and Outflows

Once students understand the structure and behavior of the basic single positive loop model of a bank balance accumulating interest, they are ready to try other structures.

- They use their models to see what happens if they add constant deposits (allowances, for example) to their bank accounts as they also accumulate interest.
- They make withdrawals from their accounts, adding an outflow.

Economics and SD *continued on page 12*

Communication Using Systems Thinking and Dynamic Modeling in K-12 Education

June 30 - July 2, 2004
Skamania Lodge, in the Columbia River Gorge, Stevenson, WA

Keynote Speakers:
George Richardson and John Sterman

The Systems Thinking and Dynamic Modeling Conference will provide resources and opportunity for educators and interested citizens to explore what is current and possible in K-12 systems education.

The Conference is designed to involve experienced individuals as well as novices in K-12 systems education.

- Teachers
- Administrators
- Curriculum coordinators
- Citizen advocates
- Business partners for schools

Presenters include:

- Teachers and administrators actively involved in systems education across the country and internationally
- Internationally known speakers and professors in the field of systems thinking and system dynamics

Our presenters and attendees will address multiple interests:

- Use of systems tools to facilitate communication in both classrooms and organizations
- Use of systems tools to facilitate critical thinking
- Learner-centered learning and dynamic modeling as part of the curriculum
- Current action research initiatives
- Improving the quality of education within local schools
- Lifelong learning and creativity in students and teachers

Our goal is to help students/future employees be self-motivated and have the critical thinking skills necessary to look at dynamic systems in an increasingly complex technological society.

The conference program topics include:

- Tools for understanding and communicating in the classroom and in school administration
- Successive improvement—how have we done it? What are the markers of our failures and triumphs?
- Where has SD made a difference? How do we assess ourselves?
- Systems Education Pathways—from varied entry points, which paths have/have not worked? How do we create them?
- System Dynamics—a vehicle for collaboration and questioning
- Presentation of systems curricula developed by teachers
- Games that illustrate a systems perspective
- Time to exchange ideas with others about systems education for K-12

The conference will run from registrationWednesday morning, June 30, to Noon, Friday, July 2. For further information, call or e-mail Andi Miller at the Creative Learning Exchange.
978-287-0070
milleras@clexchange.org

.

Skamania Lodge is a full service resort located on 175 wooded acres in the heart of the magnificent Columbia River Gorge National Scenic Area, only 45 minutes from Portland International Airport and 2-1/2 hours from the Oregon seacoast. The conference center and hotel provide flexible meeting space, comfortable guestrooms with extra amenities and spectacular views, award-winning Pacific Northwest cuisine, and a lounge open until late in the evening. Golf, tennis, walking trails, pool and fitness center are available on site.

Conference Registration Fee

The conference registration fee, per person, Wednesday AM – Friday Noon, is $435.00. (Late Fee: add $50.00 to this rate after May 15.) The registration fee includes the conference, five (5) meals—lunch and dinner on Wednesday, breakfast and lunch on Thursday, and breakfast on Friday—and a continuous break buffet. Registrants must make their own lodging arrangements.

There are three ways to register for the conference:

1. Register on-line at www.clexchange.org with credit card payment.
2. Fax your completed registration form with credit card information to 978-287-0080.
3. Mail the completed form, with payment, to us.

Registrants must make their own lodging arrangements. To reserve a room at Skamania, please call Skamania Lodge at 800-376-9116. The room rate is $139.00 per night. There are some rooms

Conference *continued on next page*

Call for Presenters—Submission date extended to February 15

Are you interested in presenting at the 2004 Systems Thinking and Dynamic Modeling conference to be held June 30 - July 2, 2004 at Skamania Lodge in the Columbia River Gorge in Stevenson, WA? The theme of next summer's conference will be "Communication Using Systems Thinking and Dynamic Modeling in K-12 Education," with an emphasis on utilizing systems tools to better facilitate communication in learning, in teaching and in administration. The conference will include the following topics:

- Tools for understanding and communicating in the classroom and in school administration.
- Successive improvement–how have we done it, what are the markers of our failures and triumphs?
- Case studies approach–where has SD made a difference both in education and in the world?
- Many people enter systems education through various doors. How do we create paths from those doors? What paths have worked or have not worked?
- System Dynamics as a vehicle for collaboration and questioning.
- Tools for understanding.
- The future of SD/learner-centered learning in K-12. How can we contribute toward it?

Please consider presenting a session at next summer's conference if you have something to say on any of the above themes or if you:

- Have taught students how to communicate utilizing systems tools.
- Have utilized systems tools to teach or help solve administrative challenges.
- Have an effective piece of curriculum to present.
- Have a story about your progress as a systems educator.
- Have an administrative application of systems tools and techniques.
- Have a progress report on a plan to get systems education implemented in your classroom, school or school district (or all three).
- Have examples of learning achieved by students through systems education.
- Have students who are willing to share insights into their learning through the use of systems.
- Have created a sequence of curriculum that seems to work for your grade level in teaching systems concepts.
- Have insights into assessing systems learning.
- Have tools for assessment.
- Have an overview of how systems education fits into a curriculum for a certain grade level and/or discipline.
- Have used systems techniques to create learner-centered learning.
- Have used systems techniques to create interdisciplinary cooperation and curriculum.
- Have an effective way of introducing systems to neophytes.
- Have a good training session for more advanced participants.

Sessions will be approximately one and a half hours in length. Appropriate long sessions (2 1/2 hours) will be considered for the workshop session, especially for training at any level or for games such as Fish Banks.

Process for submitting presentations for sessions:

- **Feb. 15, 2004** –Submit an abstract via e-mail that includes the context and history of the session topic and the experience level of expected participants.
- **Mar. 1, 2004** –All authors will be notified of the status of their submission via e-mail.
- **June 1, 2004** –A final outline/presentation or paper is due via e-mail for incorporation into the conference CD.

Additional Conference Information continued from previous page

held for early arrivals Tuesday night, June 29. Deadline for reservations at Skamania is May 15, 2004. The hotel rooms may be sold out well before this date, so register as early as possible to guarantee a room at Skamania.

Other lodging options:
Best Western, 3 miles away. For the special conference rate ($79.00 + tax, mountain view; $89.00 + tax, river view, phone 800-595-7108 and mention the ST&DM conference.

Econo Lodge, 1 mile away. For the special conference rate ($53.00 + tax/single; $63.00 + tax/double), phone 509-427-5628 and mention the ST&DM conference.

To be assured of a place, especially at Skamania, please register early. Hotels in the area also fill at this time of year, so make all reservations as soon as possible.

Transportation Information

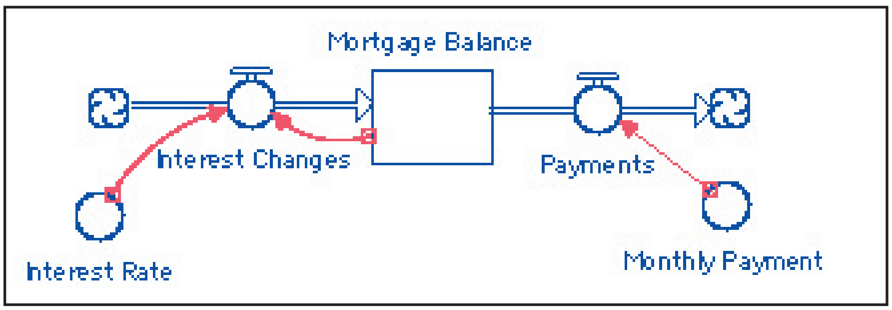
Blue Star Shuttle. 800-247-2272. $40.00 per person, one-way, Portland International Airport to Skamania Lodge. Call one week ahead to schedule roundtrip transportation; give conference name to get this discounted price.

White Van Shuttle. 877-774-9750 or whitevanshuttle.com. $65.00 1st person, $5.00 each additional person, one-way, Portland International Airport to Skamania Lodge. Call ahead.

Economics and System Dynamics continued from page 9

- They compare various savings plans. For example, is it better to save a small amount when you are young and just leave the money in the bank, or can you wait until later to start saving? This is the basic bank balance model, but students use step functions and compare the accumulations.
- In all cases, students predict what the graph will do before they run the model, practicing mental simulation skills.

Students were working on these problems when their language arts teacher approached Rob Quaden with a question about refinancing his mortgage. He had been trying to weigh the various options using a spreadsheet but he could not figure out the formulas. Quaden turned the problem over to his eighth graders and asked them to build a model that could tell their language arts teacher what monthly payments he would have to make to pay off his $60,000 mortgage in 15 or



In the students' models, the stock (the debt) had an inflow for the accumulating interest and an outflow for the monthly payments. They eagerly and easily answered the teacher's questions and learned about the concept of borrowing money to finance a large purchase. (Their language arts teacher was grateful and very impressed.)

Timber

Carlisle students do various activities using the classic system dynamics tree harvesting problem: predicting and graphing a stock of trees following different planting and harvesting policies. In the Timber Game, they use popsicle sticks to represent their trees, again using a concrete activity to help them grasp more abstract concepts. They count "trees," keep tables of values, and draw stock/flow diagrams and behavior over time graphs for different planting and cutting rates. Then they build their computer models.

For one Timber problem, students are asked to harvest twice as many trees each year (an exogenous input).This is the first time that they are asked to model a changing outflow, a new challenge. The question always arises about why a forester would want to cut more trees each year. In discussion, students conclude that people must want to buy more wood, maybe because the population is growing or because people are building more new houses. They decide that "demand for trees" should really be another stock in their model. This demand determines the cutting flow. For now, this is as far as students go with the idea, but their questions indicate a good opportunity to explore the principle of supply and demand further with a system dynamics model.

Fish Banks, Ltd.

Eighth graders play the game, *Fish Banks, Ltd.* by Dennis Meadows (UNH, Laboratory for Interactive Learning, www.unh.edu/ipssr). Playing their roles as owners of fishing companies, students chase profits by buying boats and deciding where to deploy them to fish. As their fleets grow, they face rising overhead costs and diminishing catches. Eventually, the fish stock is depleted and many of the students' companies go under. To students, this game is "for real." They are immersed in an economic system, although they do not study it expressly in those terms. Later, students build a model of the game and use it to test various policies to see if they can run a sustainable fishery. What happens if there is a tax on new boats, or a requirement to retire boats, or a limit on the allowable catch? Students implement these policies and in the process face the challenges of managing a scarce resource. They learn about carrying capacities, they make profits and decisions about reinvesting them, and they experience competition driven by the profit motive. Stepping back, they understand the tragedy of the commons and the very real risk of fish depletion in our oceans. Fish Banks raises many good economic questions.

EcoFair

Every year, eighth graders prepare individual science research projects on topics related to ecology. Although these are science projects, each student also works with another teacher on the eighth grade team to write a paper and prepare a final presentation for EcoFair, an exhibition to which local scientists, parents and the public are invited. Every project must include behavior over time graphs, as well as stock/flow and causal loop diagrams of the problem. (In recent years, students have begun using these tools to organize their writing, with improved focus and clarity in their work as a result. They are not yet ready to build independent computer models of their projects, however, beyond using the simple structures or models they have used in classes.)

The EcoFair presentations are always wonderful. Each year, the students do a better job of using the system dynamics tools to articulate their ecology problems and possible solutions. Now that they focus on a question or problem rather than just describing a topic, however, they find that they often raise many more questions. As they begin thinking about causes, it becomes clear that their issue and its solution are more complex than they first thought.

Examples of EcoFair projects:

- What is wind power's effect on reducing oil imports?
- Is genetically engineered food a problem or a solution?
- What effect would fusion power have on global warming?
- Should CAFE standards for automobile efficiency be strengthened?
- Should fishermen be allowed to increase fishing on George's Bank (off the Massachusetts coast)?
- Are hydrogen fuel cells a good alternative to fossil fuels?

These are science projects, so the students typically focus their research on the science aspects of the problem. For example, the student reporting on hybrid cars expounded on how the car operated and how fuel efficient it was, concluding that hybrid cars were far superior to internal combustion cars and should be used by everyone. Only when teachers asked him to take a look at the cars actually on the highway did he begin to consider that there may be more to the issue than just the science. Why aren't more people buying hybrid cars? What are the trade-offs? Are there hidden costs in fuel consumption? How do we weigh the environmental concerns against the economic concerns? And so on. Similar questions arise from all of the ecology projects.

Until now, the trade-offs between environmental and economic concerns have loomed unaddressed as students delved into their science research, but it is apparent that students need to consider the many factors that come into play. It is not enough to focus only on the science because the real world causes and solutions to the problems involve economic decisions as well. The issue for teachers in Carlisle is how to help students accomplish this. One possible approach is to formally introduce some economics instruction into the social studies curriculum. Since the social studies teacher already coaches individual students on their EcoFair papers and presentations, he is aware of the need for fuller explanations. Students themselves are raising the economic questions, driving the need to expand the curriculum.

TOWARD A K-8 ECONOMICS CURRICULUM WITH SYSTEM DYNAMICS

We have come to appreciate Forrester's suggestion that students need to understand economics and that system dynamics is the way to do it. But, there are hurdles. The big impediment to introducing economics goes back to the earlier issue: there is no established economics curriculum for K-8 students, and teachers do not have a deep background in the subject. We will be starting from scratch, seeking help where we can find it. The goal will be to use system dynamics models to give students an awareness of economics as it ties into other areas of their curriculum. So far, for example, the bank balance problems have been lessons in math or system dynamics that have also illuminated money management issues. We need to give more attention to economics itself in the curriculum context.

One resource will be the *Voluntary National Content Standards in Economics,* developed by the National Council on Economic Education in partnership with the National Association of Economic Educators Foundation for Teaching Economics (also available on-line). The standards outline twenty basic economic principles that students need to understand in order to effectively conduct the ordinary business of living and participate fully in our complex global economy. There are benchmarks for grades 4, 8 and 12, along with assessment criteria and available teaching materials. The standards focus on developing an understanding of basic economic concepts as they apply to the students' daily lives, in non-technical language. (They do not intend to deliver the material of a high school Economics course, for example.) Students learn about scarcity of resources, the need to make choices, weighing costs and benefits of alternative decisions, opportunity costs and trade-offs, spending and saving their money, and more, all in a context relevant to them. Our goal will be to find good ways to use system dynamics with these standards and lessons in ways that tie into the current math, science and social studies curricula. We will try to pair system dynamics with economic education from the beginning.

Another challenge to introducing K-8 economics in Carlisle is finding ways to infuse it into classes throughout the school. Rob Quaden is a systems mentor helping other teachers in their classes, but he is also an eighth grade algebra teacher for three days each week. He can easily experiment and implement system dynamics lessons with his own students. He and Alan Ticotsky (a full time-mentor) have greater difficulty establishing system dynamics lessons throughout the curriculum in other teachers' classes, however. Quaden and Ticotsky are always welcomed to co-teach with regular class teachers throughout the school, and many teachers seek them out for help with system dynamics lessons of their own. Furthermore, all teachers are now required to do at least one system dynamics lesson each year. This is very encouraging progress. System dynamics is seeping into the curriculum in Carlisle.

The issue is sustainability, however. While there are already many teachers committed to the systems approach, how can we get more teachers comfortable enough to make it part of their everyday teaching repertoire without the support of the mentors? How do we embed system dynamics so deeply into the culture and practice of the school that it continues on without us in Carlisle, and into other schools? This is the current challenge for the mentors in all areas of the curriculum. It will take steady work building on the firm foundation already laid.

Adding economic education into the mix adds to the challenge

Economics and SD *continued on page 14*

Economics and SD

continued from page 13

(Somehow, the systems approach fosters such risk-taking as Bill Gale did with his fourth graders.) K-8 teachers are already very busy, pressed to meet standardized test goals, and not always familiar with economics. There is no established curriculum for K-8 economics or system dynamics. Yet, economic issues tie into many areas of the curriculum, and students will certainly need an understanding of economics to navigate the complex global economy. As Forrester urges, system dynamics can give students a practical understanding of economic concepts. Carlisle is making a start.

Updates

continued from page 2

Waters Foundation, CVU High School, Vermont.

At this point, many of the students at CVU are exposed to systems thinking concepts through a variety of classes. Students in 9th grade science utilize the High Performance curriculum Fly a Cell, as well as behavior-over-time graphs. During the teaching of scientific inquiry, they are exposed to Connection Circles, a pre-cursor to causal loop diagrams developed in the Carlisle Public Schools. The Environmental science course has systems concepts and tools richly integrated throughout the term.

Last spring 100 9th graders from CVU were brought together to experience a disaster simulation based on SARS. Using system dynamics, the students were able to do better in their control of the epidemic than the WHO estimates.

Systemic Planning

continued from page 5

sisted. When we mentioned the pressure we were experiencing to Jay Forrester, he provided the insight that frames all our presentations. As is so often the case, Jay has the last word. He said, "The value of system dynamics must be understood as addressing the issue of understanding general policies rather than in guiding particular decisions." We continue to learn the value of this truth.

In the coming year, we look forward to sharing and discussing these insights with those of you who will again be attending the CLE conference. We want to link with others who also share the goals we have for both education and System Dynamics. System Dynamics is probably the only process we know that allows mental models to be knit together for the common good. System Dynamics speaks a language of inclusion and of the common good that is appreciated by all who have been through the process. In this it evokes the power of those earlier Concord revolutions.

The Creative Learning Exchange
1 Keefe Road
Acton, MA 01720
Phone 978-287-0070
Fax 978-287-0080
www.clexchange.org

The Creative Learning Exchange is a trust devoted to encouraging exchanges to help people to learn through discovery. It is a non-profit educational institution and all contributions to it are tax deductible.