the Creative Learning EXCHANGE

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SYSTEMS EDUCATION FOR KINDERGARTEN THROUGH TWELFTH GRADE IN THE UNITED STATES: A VIEW FROM THE CREATIVE LEARNING EXCHANGE

The Creative Learning Exchange was established as a non-profit organization in July of 1991 to support and promote the use of systems education in Kindergarten through Twelfth grade. Systems education helps students to make sense of their changing world by giving them tools to explore complex, dynamic systems. This is achieved through a learner-centered approach where students are guided in learning rather than being lectured at by teachers. Systems education starts with a more general introduction through systems thinking and then proceeds into the principles drawn from the field of system dynamics.

Jay Forrester generated the concept of creating a non-profit organization to encourage the dissemination of information to K-12 schools and teachers. His ideas were implemented through the generosity of John R. Bemis from Concord, Massachusetts. John felt it was critical that all students be able to understand the complex systems around them in order to start solving some of the earth's very complicated problems. He believed, as did Jay, that starting at the K-12 level was a necessary component for creating a society in which all people could think on a systemic level.John is often wont to say that we are all born with the equipment to learn to understand dynamic relationships. It is our educational system which trains us to think solely in a linear mode.

The Creative Learning Exchange has a two-fold purpose. One is to gather curricula and information from those who are actively involved as teachers or administrators in schools using systems thinking and system dynamics. This information is disseminated to those interested. The other is to facilitate communication among teachers and schools to help create a network of schools using systems education.

After almost three years, the Creative Learning Exchange has about 2000 people on the mailing list for its quarterly newsletter and is in close contact with the six to eight systems in the country who are the most actively pursuing systems education. There have been over 450 requests for packets of introductory information within the last year. This is a two-fold increase over the previous year.

The Educational Reform movements in the United States have fueled an increased awareness that the curricula in the public schools needs revamping. There are a number of teachers and school systems who are looking into utilizing the extraordinary conceptual and interdisciplinary power of system dynamic modeling combined with systems thinking to create positive reform. We at the Creative Learning Exchange are providing information and support to anyone who is interested in utilizing this approach.

What is going on throughout the United States?

A detailed description of the projects throughout the country is better given by those who are actively participating in them. What I can give you is a general overview of what I have observed. Since I am in contact with many projects, I am able to see some emerging patterns.

Curricular innovation with inside funding and administrative support

One place this type of innovation occurs is in school systems which are adequately funded. If such schools have a teacher or administrator enthusiastic about the concepts inherent in systems thinking and system dynamics, there are the resources readily available to get started. These schools already have the history of active involvement of the teachers in the planning of the curriculum. They have money set aside for professional development and encourage their staff to take advantage of it. The staff of these systems have been expected to grow and reach for new ideas. Support from others is likely to be generated by dedication to a good idea.

Two examples of this are the Ridgewood, New Jersey Schools and the Concord, Massachusetts Schools.

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UP-DATES...

George School

George School, Newtown, Pennsylvania is a 9-12 independent Friends' school. (See Updates—*CLExchange* Fall, 1992.) They have been working with system dynamics in classrooms for approximately four years. They have had a modest grant to encourage their work with STELLA and have taken advantage of various training opportunities over the years, the latest of which was a trip for five of them to the Systems Thinking and Dynamics modeling conference held in Concord, Massachusetts this past June.

At this point, a majority of the science teachers at the school use STELLA or system dynamics in their classroom at least once during the school year, some as many as nine or ten times. Each of these occasions is a period of about 2-5 days on the computers in their Mac lab.

Some of the units being used are the "Cooling Cup of Coffee" (see CLE list of materials), rabbit population model, lynx and hare model, radioactive decay, and growth of a cell. There is an effort across the board to give all the students experience playing and analyzing Fish Banks, Ltd.

An extra boost to the use of system dynamics at George School has come from Beth Porter, a second year math teacher. (Several lessons from Bill Enos, another math teacher at George, are available thorough the CLE.) She was exposed to STELLA in her Teachers' Education in Science and Mathematics (TESM) program at Cornell. She has brought her enthusiasm to her pre-calculus classes and is looking for ways to work some units into her Algebra II offerings.

Any questions or conversations should be directed to: Polly Lodge, Science Department, George School, Newtown, PA 18940.

FROM THE EDITOR. . .

A discussion about using a local environmental issue as an example for the use of system dynamics in the curriculum appears on page 4 in this newsletter. It is written by Debra Lyneis, a Carlisle, Massachusetts, school committee member who has been in close contact with the system dynamics community for most of her adult life. She, along with five others from the Carlisle Public Schools, attended the conference in June. She actively supports the teachers in their journey to implement systems thinking and dynamic modeling in the schools. She wrote this piece as an example of what could be done. It is terrific and is a good model for other such short examples on all levels and in all disciplines. ***If you have any such short vignettes—I would appreciate them for the CLE list of materials. It is just such pieces that are desperately needed to give to teachers who are foundering and don't know how to start. Thank you in advance!!***

Very briefly on another note—Internet accessibility of system dynamics information is slowly coming on line. Robert Gotwals (Gotwals@mcnc.org) is setting up a World-wide web page for system dynamics exchange of information. The address is (http://tfnet.ils.unc.edu/~gotwals/stella/stella.html). The MIT group is also getting an ftp site ready and operational for downloading of materials. Any questions on that should be addressed to Nan Lux (Nlux@mit.Edu).

Lees Stuntz (StuntzLN@world.std.com)

Ridgewood Public Schools

The Ridgewood Public Schools continue to keep system dynamics and STELLA on the front burner in their professional development offerings to teachers. (See Updates—*CLExchange* Summer, 1994, Summer, 1993 and Fall, 1992, as well as "The First Year: Integrating Systems Thinking and STELLA into the K-12 Curriculum" in Spring, 1993.) Six teachers from K-5 are currently enrolled in their Introduction to STELLA course and many teachers throughout the system have already taken advantage of their Introduction to Systems Thinking courses.

At the Willard School where Tim Lucas is principal, the language of system dynamics and mapping and modeling is coming into common usage in places as widely divergent as a 2-3 classroom and PTA meetings. Teachers are using the software Inspiration and SemNet as mapping tools to lead into Systems Thinking conceptualization. Tim is encouraging his teachers to start graphically mapping their professional development goals as a beginning step to both intermeshing their goals with the school's and the system's goals and also to start the discussion about system wide effects.

Any questions or conversations should be directed to Rich Langheim, Ridgewood Public Schools, 49 Cottage Place, Ridgewood, NJ 07451; e-mail: Langheim.rps@applelink.apple.com.

Nashville Public Schools

When Richard Benjamin took on the challenge of the public schools in Nashville, he had already introduced the Ann Arbor Schools to STELLA through a High Performance workshop. He brought with him the desire to use system dynamics to help guide the system toward their three goals for each child—being a life-long learner, a contributing citizen, and a productive worker.

To this end he has had Barry Richmond come out to give a week-long workshop in STELLA for six di-

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Systems Education View *continued from page 1*

These systems had both administrative support for the ideas of change in the direction of systems education as well as at least one very enthusiastic and dynamic teacher.

In Ridgewood, Rich Langheim, the Director of Management Information Services, and Tim Lucas, the Director of the Critical Thinking Program (who was then a fourth grade teacher), "discovered" system dynamics in the form of the STELLA program. Both of them thought that system dynamics would be a logical adjunct to their already thriving professional development seminar program. So they started giving courses. Over the two and a half years they have been working on systems education, they have given numerous workshops and encouraged many teachers to start incorporating systems thinking and dynamic modeling into their curriculum. Tim, now an elementary school principal, finds that he uses and teaches systems thinking as a part of his daily life. He has started courses for both parents and teachers in his school and is actively using the concepts in all aspects of his work.

The Concord schools award paid sabbatical leaves to their teachers. High school chemistry teacher Al Powers took advantage of the opportunity and spent the year exploring the field of system dynamics, writing curricula, and giving workshops for other teachers. The school system also undertook the expense of providing conference opportunities for three middle school teachers. There has been significant administrative support for Al's efforts. This year, as he has returned to the classroom, the school has provided him and a physics teacher also interested in system dynamics with seven Macintosh computers in each of their classrooms. Al has continued to make himself available to teachers within the system to give them information and support.

Curricular innovation with outside funding and administrative support

A second pattern is that of an enthusiast (teacher or administrator) within a school system implementing systems education with the help of outside funding. Another characteristic of these schools is that the support, even if not initially there, very soon came from both the teaching and administrative sides. This has happened in Tucson, Arizona in the Catalina Foothills District, as well as in Brunswick, Georgia in the Glynn County Schools.

A citizen advocate, Gordon Brown, introduced Frank Draper, a teacher in the Orange Grove Middle School in the Catalina Foothills District, to system dynamics in the form of the STELLA program. Frank and Mark Swanson rapidly implemented the use of system dynamics through the STELLASTACK and STELLA simulations in their eighth grade science program. Support for them came from the superintendent and the principal who became interested in the administrative applications of system dynamics. The principal at the Orange Grove Middle School, Mary Scheetz, has actively pursued the creation of a learning organization in her school. Her support and encouragement of teachers has produced fertile ground for the implementation of the use of system dynamics in the school.

For five years the work at the Catalina Foothills system has been supported through a grant from Jim and Faith Waters. Funding has been made available for professional development and support for the teachers to use system dynamics in the classroom at Orange Grove Middle School as well as at the new high school and across the district.

The Glynn County, Georgia project was developed by Pam Lewis, now the Assistant Superintendent in charge of curriculum, in collaboration with Georgia Pacific. Pam was able to get significant funding from Georgia Pacific to give interested teachers release time during the school year to work on curriculum. That project is now running with little or no funding but is bolstered by the continuing support of Pam Lewis and the very enthusiastic core of teachers generated by the first year of the project.

Curricular innovation with outside funding

There have been at least two examples of projects in system dynamics or systems thinking which have educated and encouraged teachers without consistent administrative support within the school systems. One, the STACI n (Systems Thinking and Curriculum Innovation and Networking) project run by Ellen Mandinach and Tony Cline of the Educational Testing Service, has been in process since 1987. It is an extensive project involving eight schools across the United States. The project has given the teachers involved extensive support in developing curricula and in using system dynamics in the form of STELLA software in their classrooms. The one high school which has been the most successful in using system dynamics in the classroom has the largest teacher base as well as some overt administrative support. There may be a critical mass factor for teachers as well as an administrative support factor working also.

The second project is the one created by a National Science Foundation grant which is being described elsewhere in these proceedings by Diana Fisher, one of the principal investigators. Their project is dynamic and exciting. Their summer institute for teachers in Portland, Oregon resulted in curricula with great potential. Ron Zaraza, one of the other investigators, states that through the summer institute they

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CONSIDER THE GYPSY MOTH: AN EXAMPLE OF SYSTEM DYNAMICS FOR CARLISLE

by Debra Lyneis, September, 1994

As we begin to consider apply ing systems thinking and sys tem dynamics in the Carlisle schools, it might help us to understand and explain just how system dynamics would "look" in our curriculum if we had a concrete example of its application. One good place to start using this tool might be in a current science curriculum, in the insects unit in particular.

Consider the gypsy moth caterpillar! Everyone in Carlisle knows and cares a lot about this pest, but we want to know more. For example, why is it that for many years we see hardly any evidence of gypsy moth caterpillars, and them, in other years, we are hit with such massive destruction of our oak trees? Once we are suddenly rid of them, why do they come back again? And, is there anything we can do about them?

This problem lends itself very well to system dynamics modeling. It appears that at least three important "levels" are involved. Levels describe the condition of the system at any point in time; they are accumulations which rise and fall over time depending on actions (called "rates") which flow into and out of them. Levels and rates are the building blocks of dynamic feedback systems. These levels and rates must be identified and then quantified in equations using the STELLA software. One must be very specific in stating assumptions about the relationships between the variables.

Our first level would be the gypsy moth population itself; we have all observed that it increases and decreases over time. A rate flowing into the level of the gypsy moth population would be gypsy moth births; flowing out would be deaths. Of course, this does not tell the whole story because other factors also exert their influence on these variables. Deaths could be due to various causes and at different points in their life cycle.

Another level would be food supply for the caterpillars, in this case oak leaves, which can also rise and fall depending on its rates. For example, the more the caterpillars eat, the less food remains; without enough food, more caterpillars die, eventually leaving more food for the survivors who then eat more, and so on.

A third level would be the size of the predator population. In this case, I am not sure what the predator is since gypsy moths are an introduced species. Maybe disease and starvation play a more important role. We'd do some research to find out. The dynamics of disease spread are somewhat different from predation, but they are both limiting factors on the population growth.

All of these levels and rates are interdependent and class discussion would certainly bring that idea out. Students would have to learn about gypsy moths, their reproduction rates, life cycles, and predators in order to accurately build this model. They could draw much of their information from their own observations and experience, but they would also have to hunt for some pieces either through research or asking an expert. It is a bit trial and

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have achieved a critical mass of interested teachers at his high school, Wilson High. Their long-term success may depend on increasing administrative support and creating a critical mass within individual buildings. Or they may, however, be able to create a critical mass within the Portland Public Schools or the Portland area to alleviate the need for administrative support.

There is yet one more school with significant progress on the systems education front. That is the Angell Elementary School in Ann Arbor, Michigan. The efforts there have been directed by the principal, Nan Gill. She has encouraged the use of system dynamics in the curriculum and has concentrated on building a learning organization, such as Peter Senge describes in *The Fifth Discipline*, in her building. When she started, she was encouraged in her efforts by her superintendent, who has since moved to another district. She, like Al Powers, was able to take a sabbatical to explore the possibilities inherent in system dynamics. Since then, she has kept the school moving without extra funding. Her enthusiasm and drive have been sufficient to make substantial progress.

It is an unanswered question as to how long systems education would thrive in the schools I have described if the people who spearheaded the effort left the schools. At what point does systems education become self-sustaining?

The combination of administrative support with a teacher who is enthusiastic seems to be a powerful one throughout all the more successful examples of implementation. Some financial support is needed to create a system-wide base. The power of one directed, enthusiastic, and hard-working person, teacher or administrator, cannot be underestimated.

Lees N. Stuntz

error, but you can see how it would be an engaging activity for kids in cooperative groups.

Once the model is built, it is simulated, or computed over small intervals of time, to see how our system behaves over time. ("Dynamics" means changes over time.) Then, to validate the model, we would fine tune it to make the simulation replicate the real world behavior of the system that we see in Carlisle: gypsy moths seem to suddenly disappear and always come back again!

Probably the following scenario would unfold in our finished model. (The results are "read" as graphs showing how the variables change over time in relation to one another.) At first there would be only a few caterpillars, so they would thrive with plenty of food. They would reproduce at their normal rate, but because their initial population is so small, we wouldn't notice them or their consumption of oak leaves. However, even a small population that grows at a constant rate exhibits exponential growth (a characteristic curve that kids would soon recognize). For example, if you double a small number, it is still relatively small; as the new number grows larger, doubling it makes a big jump, then an even bigger jump. After a few years of not much noticeable growth, the population would seem to blossom causing people to moan that the caterpillars have returned.

Meanwhile, while the population has surged in the last two years, the other two levels have been changing too. Initially, there was plenty of food. However, as the growing population devours all the oak leaves in your yard, more and more caterpillars go hungry. Many of the weaker oak trees do not survive the onslaught and die, further reducing the food supply. In the final year of the population explosion, many caterpillars die of starvation, while others die of illness from eating other foods like pine needles. To add to the drama, the predators are gaining ground too. In the early phase of the cycle, their numbers slowly grow as their food supply grows. At the peak of the caterpillar growth, they have almost reached their peak; they can feast on the overabundance of food and multiply.

The resulting impact of the decline in food and the increase in predators (both initially spurred by the growth in the gypsy moth population) results in the dramatic collapse in the gypsy moth population. They seem to be wiped out. The following year, the continuing large population of predators almost finished the job, but it too declines rapidly because it has little food left. And now we are right back where we started, ready to go again. It is a natural cycle.

Once the model seems to run correctly, (that is, it accurately represents past behavior of the system) you can begin to play with it. You can perform experiments on the simulated system without the risks, expense, or uncertainties of experimenting on the real thing. Does trying to kill the caterpillars on your trees as the population becomes a nuisance really have any impact or does it just delay the inevitable by providing more food for the rest? How about cutting down some or all of the oak trees? What about the predators? What leverage can we apply to the system there? Are the wild swings in gypsy moth population related to the fact that it is an introduced species? We could simulate all of these conditions and see what happens. And there are, of course, broader questions that arise. Can or should we try to tamper with natural system cycles? What similarity does this system have with other systems in our experience?

You can see that kids would find this engaging. It is a big puzzle that they construct based on their own knowledge and experience. As they play with it, they are learning a lot about insects, ecology, cycles, and systems all around us.

In our sixth grade, the students would not yet have the skill to build the model. We would have to build it first and get it to run properly. But, we could lead them through the process, so that it becomes their model to play with. (STELLA provides a special authoring software which makes this easier.) In the long run we might expect our students to begin to conceive their own models. We would need a lot of preliminary units, starting early, to get there.

This isn't the only model we could do, nor do we have to do this one if others would fit the curriculum better. It is just an example. The appeal of this one is that it is familiar, very concrete, and part of the curriculum. Everyone in Carlisle would resonate to it! (My kids hate standing in the slimy green droppings at the bus stop, or finding caterpillars in the mailbox!)

This gypsy moth model is a relatively simple one, but that is not to say that building it is easy. It is a challenge to begin to think in this way and to take a multi-disciplinary approach to learning. It is a skill that takes practice. Working together, we'll all get there (Not surprisingly, kids take to this naturally. Our compartmentalized, fact-oriented education must have taught it out of us!)

Also, this model applies to the science curriculum, but we should try to broaden our aim as soon as we are competent and confident with using system dynamics as a curriculum tool. With the gypsy moths we can almost predict the behavior of the system, because it is small and easily defined and observed. However, once you get into bigger models of more complicated systems, you cannot predict the outcomes. Cause and effect may be distant in time and space; our mental models cannot encompass them. This would apply to systems like human population growth, the development and decay of

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verse groups, including teachers, administrator and community members. The community members from the Bernstein Center for the Performing Arts have used their STELLA training to create a model of different endings to *West Side Story*, and are creating performances to go with the different endings.

Another pod of learners in the training session was those concerned with *Success by 6*, a community based program to bring students into the schools with adequate health and nutritional care, and to help eliminate prematurity in newborns, as well as to give support through the early years to get children off to an optimal start. Exciting partnerships with United Way and Dollar Stores has sparked this program.

Dick is looking for other administrators who are interested in discussing the uses of system dynamics as a tool for staff development, strategic planning and curriculum

Any questions or conversations should be directed to: Dick Benjamin, Superintendent, Metropolitan Nashville Public Schools, 2601 Branford Ave, Nashville, TN 37204.

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a city, the causes leading up to the Civil War or the American Revolution, our intervention in Somalia or Haiti, and so on. The tools for building these models would be the same as those for the gypsy moth (and so would be the underlying system structures). However, we would save the more abstract models, like social studies, for later, when our modeling skills are more sophisticated and when we have gained more confidence in tackling bigger ideas and controversies using the tool of system dynamics. This is the arena for teaching the critical thinking skills so necessary for the future, as described by Jay Forrester. It will be a growing process for us all.

This is just a start. It will be exciting for us all to take it further, one step at a time.

INTERESTED IN INVESTING?

All of us are interested in promoting the use of systems education in our schools. A number of you have asked if there is a charge for the services of the Creative Learning Exchange, or what you can send to help defray the costs of printing and mailing to you.

The Creative Learning Exchange will continue to send out materials free of charge to all those on the mailing list, regardless of their desire to invest at this time. However, if you would like to invest in our effort here at the Creative Learning Exchange, your contribution would be appreciated. You may donate any amount you wish; perhaps $25 is a reasonable amount for a year. All contributions are tax-deductible.

I am sending _____ to *The Creative Learning Exchange* to help invest in the future of systems education .

Name_____

Address_____

Thank you!!

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