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BRINGING SYSTEM DYNAMICS TO A SCHOOL NEAR YOU
Suggestions for Introducing and Sustaining System Dynamics in K-12 Education

Debra A. Lyneis, for the 2000 International System Dynamics Society Conference in Bergen, Norway

The key to system dynamics in kindergarten through twelfth grade (K-12) education lies in the classroom—in the interactions between teachers and students. Experience has shown that when systems instruction succeeds at this level, the education process is greatly enhanced for both students and teachers. Education becomes more learner-centered, engaging, interdisciplinary and relevant for students of all ability levels, across all grade levels and subject areas. Experience has also shown, however, that it can be very difficult for one teacher to achieve this success all alone. Such a fundamental change in education needs the support and cooperation of many other people from both within the school and without. A supportive school administration is essential. But, parents, system dynamicists, academics, businesspeople, and taxpayers also play vital roles.

Systems education has begun to flourish in several pioneering schools across the United States, thanks to the skills of enthusiastic teachers and the help of others. However, the continued growth of this change in education will rely on the contributions, both large and small, material and intangible, of a wider circle of supporters. This paper will explain how system dynamics is introduced and sustained in schools. It will outline some of the many generous contributions that have made the early growth of K-12 system dynamics possible. Finally, it will give readers many resources and practical suggestions for how they can participate too.

INTRODUCTION

Over the last decade, system dynamics and systems thinking have begun to make their way into kindergarten through twelfth grade (K-12) education in the United States. In several pioneering schools across the country, system dynamics is becoming an integral part of the curriculum and systems thinking is permeating the culture and management of the school. Teachers using the approach have found that it enhances their current curriculum by making it more learner-centered, interdisciplinary, and relevant. Using behavior over time graphs, causal loop diagrams, stock/flow diagrams and system dynamics models, students become engaged in working together to understand the causes of problems across disciplines. Teachers are often amazed by

***Suggestions** continued on page 3*

WHAT'S THE RUSH?

Fourth in a series of "What It's Like to Be a Pioneer"

Prepared with the support of the Gordon Stanley Brown Fund by Debra Lyneis

*Jay Forrester has suggested that we could speed the spread of system dynamics in K-12 education by sharing tales of "what it's like to be a pioneer." It might help others who are starting out, or just curious, to know about other teachers' experiences, triumphs and tribulations. This paper presents just one little vignette. Please let Deb Lyneis know (*LyneisD@clexchange.org*) if you have other tales to share.*

Here is a practical application of system dynamics, powerful in its simplicity.

Dan Barcan's seventh and eighth grade students at the Murdoch Middle School, Public Charter School of Chelmsford, Massachusetts store their work portfolios in a crate at the back of the classroom. Whenever Dan asked the students to get their portfolios, they would swarm to the back of the room and mob the crate, pushing and shoving all at once to find their own folders.

Although this was typical behavior for young adolescents, it was disruptive and it wasted too much class time. In an effort to help students retrieve

***Rush** continued on page 16*

UPDATES…

Williston Central School

A team of students, educators, adults, and local officials will be formed as an in-school "think tank" at Williston Central School (WCS), in Williston, VT. Initially, students and interested adults will be trained in the tools and methodology of system dynamics. The training has been in place for the past three years at the school, having been conducted by Will Costello, Mentor-Teacher. (Will Costello has taught high school science for 20 years and is currently the Systems mentor-teacher for Chitttendon South School District and Champlain Valley Union High School. He will provide professional systems expertise, program assessment, and publication of results.)

Concurrently, working with the Williston School-to-Business Co-ordinator and local officials, the program will research and solicit concrete examples of problems/questions that the team can address. Examples of pre-existing problems/questions which the team could approach might include: the impact of sustained population growth upon WCS enrollments, the impact of increased traffic flows on actual and perceived quality of life, and population and sewage capacity issues.

Teams of students from the WCS group will partner with interested adults and community leaders to conduct group modeling exercises to model the selected issues, with the objective of increasing understanding about the system under study, and propose policy options to address concerns derived from the process. Assessment of student work, based upon the Vermont Standards, and public presentation of research and findings, are requirements for all participants. This will include group presentations at DynamiQue***ST*** 2001 in Boston, an international exhibition of student work in the field of system dynamics.

Students will meet twice weekly, during the school day, and will be selected from all "Upper Houses" (Grades 5-8). The selection process will be determined in collaboration with the WCS Leadership Team and appropriate House faculty.

Will Costello

DynamiQue*ST*

The DynamiQue*ST* committee from last year is at work again to create a celebration of the work students in grades 5-12 are doing in system dynamics and systems thinking. Last May, our celebration, held at Trinity College in Burlington, Vermont, was very successful. Nearly 30 students participated. Through a poster session, they presented their projects to coaches experienced in the field of system dynmaics. They also participated in systems games and activities, as well as a group problem-solving session. All three different activities were highlighted by a chance to be in a dorm with fellow students.

The emphases this year will be on increasing the feedback each child receives individually from the coaches who talk with them about their projects, and giving other students a chance to help coach their fellow participants. The group problem-solving session, led last year by George Richardson, was a wonderful learning experience for all involved. Every effort will be made to create that sort of experience again for us all.

The two dates we are pursuing with various sites are May 11-12, or May 31-June 1.

We welcome any participants who wish to join us. Please contact Lees Stuntz <stuntzln@clexchange.org> if you wish more information on this exciting event.

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EDITORIAL

We are hoping, after several disappointing dry winters, that the lovely white Christmas and subsequent heavy snowfall in the Northeast are indicative of a real winter with lots of good skiing and snowshoeing. As we all settle down after the holidays, the activities at the CLE include sorting through all of our materials and updating as necessary. We want to really look at what we have to help people get started, or to continue, in the use of system dynamics and systems thinking in their classroom or school. If you would like to tell us what you have gotten from the CLE site which has been useful to you, we would love to hear about it!

Please tell us what you think of our revamped site, which curriculum or papers you have found inspirational or helpful, and, above all, what you suggest we can do for additional improvement.

We look forward to hearing from you.

Lees Stuntz *stuntzln@clexchange.org*

The Creative Learning Exchange Newsletter is available in three formats:

- On the web page at www.clexchange.org
- As an attached file to an e-mail
- In paper via US mail ($15.00 outside the USA)

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Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 1

what their students can do—they ask better questions, seek their own answers, and gain deeper insights than they did before. As other teachers have observed these benefits for students, they have also tried the approach in their classes. Now the ideas of systems education are appearing more frequently in education publications and at conferences, and many other teachers and administrators are giving them a try.

System dynamics in K-12 education took root in schools in the late 1980's when Gordon S. Brown, an interested citizen and retired MIT Dean of Engineering, introduced STELLA software to one middle school teacher, Frank Draper, and his principal, Mary Scheetz, in Tucson, Arizona. (More than a decade earlier, Professor Nancy Roberts at Lesley College had pioneered the idea of introducing the concepts of system dynamics to young students, but it was not until system dynamics software had a user-friendly graphic interface that the practice of system dynamics could become more accessible to K-12 students.) Encouraged by the early achievement of the Tucson students, several other people outside of schools joined the effort to infuse and sustain positive change in education through system dynamics on a national scale. Jay W. Forrester, founder of the field of system dynamics, Jim and Faith Waters, and John Bemis have provided visionary guidance, generous funding and information so that teachers and administrators in diverse schools across the country could work together to improve their own schools.

As system dynamics has spread to several other schools across the country, countless other volunteers have become involved. While the key to system dynamics in education lies with the classroom teacher and his/her students, experience has shown that it is difficult for a single teacher to sustain the effort alone. Most of the pioneering schools that are succeeding have benefited from the outside support of parents, taxpayers, local businesses, local colleges, professional system dynamicists, and foundation grants. Contributions have been large and small, material (computer equipment, money) and intangible (coaching, encouragement, recognition). Every contribution has been valuable. In this still early stage of K-12 systems education, many other schools will also need outside support for impetus and assistance to improve through system dynamics.

The goal of this paper is to provide specific recommendations based on experience to those who would like to help implement change in their own schools. The first section will describe how system dynamics fits into the K-12 curriculum, followed by two sections explaining the process by which system dynamics takes root and grows in schools. The remaining sections give examples and advice on how to get involved. One section reviews the contributions of early leaders and another cautions against a common pitfall. The final half of the paper is a catalog of specific activities and resources to help implement system dynamics, systems thinking, and learner-centered-learning in schools. These recommendations are based on conversations and correspondence with many teachers, administrators, and their supporters at schools across the country. They are also based on my own experience in the Carlisle Public Schools in Carlisle, Massachusetts.

WHAT IS SYSTEM DYNAMICS IN K-12 EDUCATION, AND WHY?

In K-12 education, system dynamics is not taught as a separate subject for its own sake. Rather, it is a tool to make current instruction more effective for students. Teachers view the systems approach as a way to do what they are already doing, only better. For example, students use behavior over time graphs to find patterns in historical trends, in literary plot developments, or in science experiment results. They use causal loop diagrams to focus discussions on unintended consequences in environmental studies or patterns of escalation in social conflicts ranging from playground squabbles to the American Revolution. They use stock/flow diagrams to understand population dynamics in various contexts: the extinction of mammoths in social studies, the growth of yeast cells in a test tube in science, the concept of exponential growth in math. Finally, they tie all of these skills together and use system dynamics models, or build their own, to gain an even deeper understanding of whatever they are studying.

Teachers find that, in the process of using these tools, students' learning becomes more learner-centered and cooperative. In the traditional approach, teachers stand at the front of the class and dispense information about separate subjects to students who are passive receptacles. In contrast, the systems approach sparks inquiry and enables students to take charge of their own learning, something they are naturally driven to do. System dynamics encourages students to figure things out, put puzzle pieces together, look for similar patterns, and work together to ask questions and find answers across disciplines. These goals are not new. Teachers are always looking for ways to invest students in learning, and cooperative learning and interdisciplinary lessons are accepted ideals. With system dynamics, however, they all fall together naturally, to the great benefit of children. In elementary and middle school, the work is genuinely interdisciplinary. At the high school level, because of the rigidly compartmentalized structure of the curriculum, system dynamics is more often confined to individual subject areas, or even taught as a separate elective. At all levels, students do not do system dynamics all the time in every class—they still cover "the basics." But, the systems approach does seem to make education more fun for students and teachers alike.

Suggestions *continued on page 4*

Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 3

Making education more engaging is a worthy goal in itself, but system dynamics in education offers more than that. It equips students with the skills and perspective they will need to effectively address the dynamically complex social, economic, technological and environmental problems facing them in the future. These are real-life needs. Education that was "good enough" for us in the past may not be good enough for the challenges facing tomorrow's world citizens.

HOW DOES SYSTEMS EDUCATION BEGIN IN A SCHOOL?

The successful spread of systems education follows the infection model. It starts with one or two teachers in a school who are looking for ways to improve their curriculum for their students. They try using one of the systems tools in a lesson and often get "hooked" when they see how eagerly and insightfully their students participate. On their own, these teachers try to learn more about the approach and find other applications to their curriculum. If that goes well, they invariably tell their colleagues about it. Then, other teachers try the ideas with their students. System dynamics spreads very slowly from the grassroots as teachers recognize its benefits for their own students.

This process can work in any kind of school. Systems education has taken root in such diverse places as the middle schools of rural coastal Georgia, the public high schools and a parochial high school in Portland, Oregon, a private elementary day-school in Toledo, Ohio, an inner-city New York school, a charter school in Chelmsford, Massachusetts, rural schools in northern Vermont and suburban schools in Carlisle and Harvard, Massachusetts. Some people believe that the middle school level is a good place to begin because of the developmental level of the students and the flexibility of the middle school structure, but success has come in elementary schools and high schools as well.

The only requirement for any school seems to be openness to innovation and improvement. A tightly tradition-bound school or a complacent school is less likely to have the willingness or creative tension to reach for a better way to serve kids. Even in these schools, there may be fine innovative teachers willing to try system dynamics on their own. However, in an innovative school, led by a supportive administration, systems education will more easily spread to other teachers and to the culture of the school itself. A supportive administrator can provide leadership by allocating resources, adjusting schedules, encouraging participation, facilitating collaboration, securing professional development, cutting red tape, dealing with the public, and holding the line on other competing initiatives. These are all important.

In some cases, systems education has entered a school through an administrator who used systems thinking in the organization and management of the school. An administrator who espouses the principles of systems thinking and values continuous improvement, teamwork, and working toward a shared vision is likely to support the same approach in the curriculum. If that administrator introduces system dynamics tools to a teacher and the teacher finds merit in them for students, then the infection process takes hold in the curriculum. There is great synergy when teachers are working from the curriculum up and administrators are working from the top down to improve education with the systems approach.

ONCE BEGUN, HOW IS SYSTEMS EDUCATION SUSTAINED?

The infection model describes how system dynamics begins to grow in a school: It starts with one teacher trying one lesson and eventually spreads to other interested teachers. This early stage requires patience because the process seems very slow—like any exponential growth, initial growth appears flat for a long time until more people are involved.

However, once a few teachers become interested in the approach and begin using it more often with their students, maintaining the infection process in a school becomes much more complicated. New growth is still driven by enthusiastic teachers who observe the benefits for students and try it for themselves. However, sustaining the efforts of the first teachers and managing the further spread of system dynamics and systems thinking throughout the curriculum and culture of the school require much greater support and patience. Although the process takes a different course in each school, the basic needs are similar:

- **Training.** Teachers need organized training to learn about system dynamics and how it applies to their curriculum. After the training, they need follow-up support and coaching. System dynamics is not easy to learn. Unlike grammar and arithmetic, teachers did not learn the basic principles of systems in school, so everyone is starting at the beginning. Teachers who do not get early training and support when they need it can get discouraged. They also may use systems tools inaccurately. Training and follow-up support are an ongoing need.
- **Time to accept the ideas.** The ideas of system dynamics and systems thinking are new to most people and not immediately obvious. Teachers and administrators need the time and respect to digest and assess them at their own pace. The first few adopters may embrace them quickly, others will take more time, and some may not be interested at all. These new ideas cannot be forced onto others.
- **Time for collaboration.** Teachers need time to work together to develop their skills, design interdisciplinary lessons, and share successes and frustrations. (It is also very helpful if teachers and administrators can network with colleagues in other schools.)

- **Transferability.** Schools need to facilitate the transfer of the use of systems tools across disciplines and across grade levels in order to unify the curriculum and intensify the power of system dynamics for learning. Teachers and students need to see that system dynamics is not just a science "thing," for example. The tools and structures are generic. This takes planning.
- **Organizational learning.** Similarly, schools need to consciously apply the principles of systems which they have learned in the curriculum to the functioning of the school. This is a leap for most people, but enlightening if they can make it. It takes time.
- **Equipment.** Schools need computers and system dynamics software.
- **Administrative support.** This is *essential* to all of the above. Teachers need a supportive administrator who "owns the process" and facilitates the growth of systems education throughout a school in many ways.
- **Community support.** Schools need the support of parents and other taxpayers as they propose to change and improve education using the systems approach. Schools need to keep their communities informed and listen to their concerns.
- **Patience, trust and vision.** These are also essential. Instituting change in education is not easy. Education is under tremendous pressure to improve to meet the demands of an increasingly complex and rapidly changing society. However, it is an institution which changes very slowly—it has a finely tuned "immune system" that maintains stability and resists any pressure to change abruptly. Teachers, administrators, and supporters need patience to accept that real change grown from the grass roots requires time and creative perseverance in the face of obstacles. They need trust to work effectively together. And, they need a shared vision that education must and can improve. These can all be engendered and renewed by observing kids engaged in good systems lessons.
- **Money.** Patience, trust and vision are all free, but schools need to find money for training, teacher time and equipment, all at a time when school budgets are very tight.

WHAT CAN YOU DO TO AID THE PROCESS?

The rest of this paper will give you ideas and resources for getting involved. It will give examples of contributions that others have made to schools across the country as well as advice based on their experience on how to proceed. There are many ways, large and small, to help schools meet their needs. You should read over the suggestions and choose an approach that fits best for you and your school. A few people have invested enormous amounts of time and money, while countless others have made small but equally important contributions. Whatever you give will be a worthwhile contribution to the improvement of education.

Remember that system dynamics in education is still in its infancy, and there are no complete how-to guides. Only a decade ago, teachers and administrators in the few schools trying this approach were truly pioneers. They experimented as they went along, sustained only by the conviction that education had to improve and that system dynamics and learner-centered-learning offered a very promising alternative. Their success with students has led others to follow. Now, other schools can learn from the growing experience of those who are using the systems approach. Yet, this is still very new and still involves a great deal of experimenting, explaining, searching, collaborating, and tolerating the uncertainty that accompanies change. There is still pioneering to do. Every tiny bit of progress paves the way for others to follow.

EARLY LEADERS SET THE STAGE

Several outside supporters have made very large contributions to launch and maintain system dynamics in K-12 education. As you look for ways to serve your school, it is important to learn a bit about their efforts because, over the years, they have established a framework and resources for others to use. Also, this is an opportunity to acknowledge their generosity and visionary guidance.

Jay W. Forrester

First among advisors to K-12 system dynamics, has been Jay W. Forrester, MIT Professor Emeritus and founder of the field of system dynamics. Probably the first to understand that transforming education through system dynamics would have to be a grassroots effort, he has personally enlisted the involvement of system dynamicists and other backers to support the work being done by teachers in classrooms. He has continually urged teachers to extend systems education into younger and younger grades so that growth and change can flow upward with those children. He has insisted on quality and more system dynamics training for teachers, reminding us that unfortunately "there is no easy way to get beyond the beginning steps." Yet, he has also encouraged us to learn from mistakes, of which there have been plenty, because mistakes are our best teacher. He has constantly challenged everyone to consider why current K-12 education is not relevant to today's kids and tomorrow's problems, lighting a fire under those who believe it can and must be better. Finally, he has provided the long view. Change takes time. And, although many may feel that this change in education is progressing too slowly, Forrester believes that the pace is just about right for long term sustainability.

[For more on Forrester's views on K-12 system dynamics, visit the Creative Learning Exchange (CLE)

***Suggestions** continued on page 6*

Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 5

website (http://www.clexchange.org). Under the annotated list of Systems Education Materials, read Forrester's *System Dynamics and Learner-Centered-Learning in Kindergarten through Twelfth Grade Education* (SD1993-01) and *Learning Through System Dynamics as Preparation for the 21st Century* (SE1994-07). Also, under the list of System Dynamics Materials, read *Designing the Future* (SE1999-03). The the System Dynamics in Education Project (SDEP) website at MIT at http://sysdyn.mit.edu provides an introduction to the field of system dynamics and links to many related publications and sites. It provides a wealth of information worth the time to explore.]

Gordon Stanley Brown

Another pioneer in improving education through system dynamics is the late Gordon Stanley Brown, former Dean of Engineering at MIT. In fact, he first got the ball rolling in schools. In retirement, Brown was living in Tucson, Arizona in the late 1980's when he attended a neighborhood school bond vote meeting. There he spoke to the superintendent of schools about system dynamics and was referred to science teacher Frank Draper at the Orange Grove Middle School. Draper saw system dynamics and STELLA modeling software as just what he had always needed in his curriculum. He used it extensively, encouraged by the breadth and depth of understanding his students eagerly displayed with this approach. As other teachers in the school also became interested, their work was strongly supported by the principal, Mary Scheetz, who also had a gift for applying the principles of systems thinking to the organization and management of the school.

Meanwhile, Brown became Orange Grove's "citizen champion." He marshaled resources for computers and STELLA training, lobbied school board members, ran interference in every direction in a low-key but persistent manner, and encouraged Mary and Frank to keep going. In Mary's words, "Gordon was a visionary—seeing the possibilities both in the classroom and in the organization. He gave us the motivation and courage to stick to our ideas about becoming systems thinkers and also using dynamic modeling." This was not easy, and early progress was very slow, but now, twelve years later, systems thinking is an integral part of the Orange Grove Middle School and its Catalina Foothills School District. And, just as that school has become an example for other schools to follow, so is Gordon Brown an example of what the support of a citizen champion can achieve. [For more from Brown's point of view, read his *System Dynamics Review* article *Improving education in the public schools: innovative teachers to the rescue* (SE1993-01)on-line at the CLE website, http://www.clexchange.org, under the List of Systems Education Materials.]

Jim and Faith Waters

Two other dedicated citizens, Jim and Faith Waters, have contributed generously to the continued success at the Orange Grove Middle School and to many other schools across the country. Jim is a successful entrepreneur with a long commitment to public education, having served on his local school board in Framingham, Massachusetts. Faith is a retired public school teacher. Together, they believe that education can and must improve, soon. They began slowly by funding systems mentors in the Tucson school—a couple of teachers whose job it became to help other teachers apply systems tools in their curriculum. Jim and Faith also funded systems training for the mentors and the time for them to meet and work together.

Now over a decade later, the Waters Foundation supports systems education in about a dozen school districts across the country, helping to further the work that these schools had already begun on their own. The foundation funds the salaries of teams of systems mentors in these schools. In addition, grants have purchased computer equipment, sponsored continuing system dynamics training for mentors and workshops for teachers, and hosted annual national gatherings of all mentors to aid the cross-fertilization of curriculum ideas. Most importantly, Jim and Faith have offered their guidance, trust, and patience to teachers and administrators involved in this exciting but sometimes daunting endeavor. The Waters Foundation is now administered by Mary Scheetz and four regional coordinators. Under Jim's and Faith's direction, the foundation is now focussing on solidifying the best teaching practices and lessons developed over the years to make them accessible to teachers in other schools everywhere. Their schools have been laboratories to get things started. Now they are concentrating on documenting the use of system dynamics in the learning process and disseminating successful lessons to others. The Waters website will be up and running soon at http://www.watersfoundation.org.

John Bemis

Finally, one other quiet contributor has helped bring teachers and systems curriculum ideas together. In 1991, John R. Bemis of Concord, Massachusetts generously established the Creative Learning Exchange, a non-profit organization to promote and support the use of systems education and learner-centered-learning in kindergarten through twelfth grade. Under the direction of Lees Stuntz, the CLE gathers and distributes systems curriculum materials developed by teachers for other teachers. The CLE also publishes a free newsletter, *The Creative Learning Exchange*, and it hosts a well-attended summer conference for teachers each even-numbered year. For more information on the CLE, visit their website at http://www.clexchange.org. Peruse the Annotated List of Materials to down-load articles and curriculum materials for free. This is a good way to get a better idea of just what systems education looks like in the classroom.

ONE PITFALL: DON'T PUSH TOO HARD!

The advice most often repeated by those involved in systems education is "Be patient—don't push too hard." If you want to facilitate lasting change in education, your long-term results will depend to a large extent on *your approach* to the school and the process of change. The school needs to be open to new ideas, but more importantly, you have to be willing to work *within* the structure of that school to make a difference. Davida Fox-Melanson, Superintendent of the Carlisle Public Schools, recommends that you approach the school with the intention of understanding, supporting, and strengthening education there. Get an idea of what goes on in your school and listen to what kids are learning. See if you can find out what teachers need in their curriculum and look for places where systems tools can help fill those needs. As enthusiastic as you may be about systems education, it is a mistake to go barreling into a school as an expert with all the answers. Instead, build a collaborative relationship based on trust. If one or two teachers are interested, give them information and support, and build patiently from there.

You cannot force the process of change. Good teachers in a supportive environment are always seeking better ways to help children learn, but they are also already extremely busy and under intense pressure to produce results. They need to be engaged but not threatened by these new methods. To succeed, your intervention must be careful and respectful, trusting teachers to approach it in their own time, whether you are dealing with just one person or with a whole school.

Unfortunately, the infection process takes time, and this can be very frustrating. The slower it seems, the more likely you will be tempted to push. However, your pushing too hard will slow progress even more. It is only natural to want education to improve quickly. However, if you push too hard in your eagerness, you will have to learn this lesson the hard way: The system pushes back. Nan Gill, former school principal in Ann Arbor, Michigan and now a Waters Foundation regional coordinator says, "Be aware of the potential positive feedback relationship between outsiders' pushing and insiders' resistance, particularly given the current climate of school criticism that pervades our society." The harder you push, the greater the resistance. Outsiders can help, but real progress can only come when you work within the system helping the school staff "own the process" itself.

If you barge into a school with all "the answers" and expect immediate change, you will not make any progress. If you are openly critical of the current system, you will offend teachers and administrators who work very hard for their students, and they will not listen to you. If you approach the school more positively but you do not build trust first, teachers and administrators may listen, but they will not adopt your ideas. If you do not demonstrate to teachers how this approach can help them teach what they are already teaching, only more effectively, they will not abandon their own methods—they have managed for many years without systems thinking, so why would they need it now, especially if it involves a lot of extra work? If you expect teachers to learn system dynamics too quickly, they will become frustrated and overwhelmed and give up entirely. It is a delicate balancing act. You want to advocate for education reform, yet you need to be aware that your own actions in pushing too hard will cause your best intentions to backfire.

One School's Experience: Pushing Too Hard

We experienced this in Carlisle, Massachusetts when we were just starting out. In 1994, when I was serving on the school board, Carlisle seemed to be "fertile ground" for systems education with two interested teachers, a supportive school board and a superintendent who had just read Senge's *The Fifth Discipline* and agreed with it completely. We also had Jim Lyneis, a professional system dynamicist and management consultant at Pugh-Roberts Associates/PA Consulting, as a knowledgeable system dynamics resource. We had a fine school, but we all believed that we could do better. System dynamics looked like a perfect fit to me. How could we miss?

In my enthusiasm, however, I pushed too hard at first. We set up after-school modeling sessions with Jim, but it became just too much. Everyone started with the best intentions, but once the teachers realized that modeling was more difficult than it first appeared, they felt discouraged by the amount of time and work required. Meanwhile, Jim and I were discouraged because progress was so slow for our time and work required. In the end, sessions were delayed or cancelled until the whole plan fell apart. Fortunately, Davida Fox-Melanson, our superintendent, stepped in to remind us all that, while system dynamics still might have potential for us, we would have to take it more slowly. In other words, "Back off for now." It was a lesson learned the hard way for me and a very long time before I could convince the teachers, or Jim, to give it another try when we were more ready. You cannot push these ideas onto people. For lasting change, people need to perceive their own need and proceed at their own pace in their own time.

Fortunately, the teachers continued to experiment with systems lessons in their classes—their reinforcement came from the students themselves. Luckily, we also continued to share trust, respect, and a conviction that education could be better. Progress was very slow for several years and hampered by setbacks, but somehow system dynamics grew on its own merits, fueled by the enthusiasm and achievement of students. Now the infection is finally catching on and the

Suggestions *continued on page 8*

Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 7

results are promising. Two teachers, Rob Quaden and Alan Ticotsky, are now systems mentors supported by the Waters Foundation. Working with classroom teachers over the last two years, they have introduced behavior over time graphs, causal loops, stock/flow diagrams, and computer modeling throughout the school's curriculum, in kindergarten through eighth grade. Also, under Davida's leadership and with the help of business manager Eileen Reilly, systems thinking is very slowly seeping into the school culture. We are still beginners making frequent mistakes, but every little success reinforces growth. My pushing too hard nearly spoiled it.

Others can tell similar stories. It is natural to want change to come fast to an education system that sorely needs it. However, you can actually delay change by fighting against education's immune system. Realize that everybody gets frustrated with the slow pace of change at times. You can think big, but you have to be satisfied with slow tiny steps if you want to succeed in the long run.

PRACTICAL SUGGESTIONS: SCHOOL NEEDS AND HOW TO HELP MEET THEM

The caution to have patience and proceed slowly is not meant to discourage participation in schools, however. In fact, there are a great many ways to contribute, large and small, material and intangible. Also, many people can play a role: parents, system dynamicists, taxpayers, academics, businesses, and foundations. The following catalog of suggestions and resources is based on experience in schools so far and the contributions of many generous supporters. You can help with information, system dynamics demonstrations and expertise, training, equipment, public relations, business support, and encouragement. This is not an exhaustive list, but rather a guide to give you ideas. Just choose one activity for a start and have fun with it.

Information about Systems Thinking and System Dynamics

Offer to introduce these ideas to teachers or administrators. If there is a teacher in the school who is already using systems tools, work with the teacher to explain the ideas to others.

- Give the school several copies of the Creative Learning Exchange newsletter, *The Creative Learning Exchange*, and arrange free subscriptions through the website http://www.clexchange.org or by calling the CLE at 1-978-287-0070.
- Review, download and print articles or curriculum materials that might be useful to your school from the Creative Learning Exchange website to give to teachers and administrators.
- Introduce teachers to the Creative Learning Exchange website http://www.clexchange.org and tell them about other related sites:
  - System Dynamics in Education Project at MIT http://sysdyn.mit.edu
  - CC-STADUS/CC-SUSTAIN http://www.cc-stadus.com (Portland, OR)
  - Maryland Virtual High School http://mvhs1.mbhs.edu
  - Waters Center @ Trinity College http://trinityvt.edu/waters
  - Waters Grant-Systems Dynamics Project http://www.cfsd.k12.az.us/~sysdyn (Tucson, AZ)
  - Waters Foundation http://www.watersfoundation.org
- Offer to set up a little professional library of systems books and materials. (See Appendix A for a suggested list.) The idea is not to hand your school a stack of books that will collect dust on a shelf. Instead, ask teachers and administrators what they need and try to meet the need with whatever seems appropriate.
- Find or donate the money to send a team of teachers and administrators to the CLE summer conference (registration plus travel funds). This is a wonderful way to introduce your school to the ideas and practices of systems education and to build a team. (This is how Carlisle got started. We begged for a grant to attend the CLE conference in Concord, Massachusetts in 1994.) The conference is always well-attended by teachers eager to learn and share ideas. Many of the leading professional system dynamicists are also there to share their expertise. This is a great way to get started and an excellent investment.

System Dynamics Demonstrations

- Offer to demonstrate to a class how system dynamics tools apply to a particular lesson. Do not show off the tools themselves; apply them to an issue that students are studying. Work closely with the classroom teacher.
- Offer to conduct the *Fish Banks, Ltd.* game with a science class. (Meadows, http://www.unh.edu/ipssr/Lab/FishBank.html) Students as young as 8th grade can play, and they love it. Work closely with a teacher on logistics for kids.
- The absolute best ambassadors for systems education are the students themselves. Whenever you can, let them do the talking about what they have learned using this approach. According to Tim Joy, a teacher at LaSalle High School in Portland, Oregon, " I have yet to witness any public event with students in which adults were not swayed. The authentic power of their deep understanding exudes a salutary effect." Students voluntarily spread the word when they carry their ideas home or into other classes. If you have students using systems tools already, do whatever you can to support them. Systems

education is much easier to show in action than to explain in words; the students, after all, are the whole point.

- Let your own children lead the way. If your child is working on a project that could be explained with a behavior over time graph, a causal loop diagram, or even a simple model, teach these skills to your child and let him explain it to the class. We did this with our kids. When Peter was in the 8th grade, he did a project exploring why Spain and Canada were sparring over North Atlantic fishing rights. Jim helped him build a one-stock model of the tragedy of the commons. Peter's teacher, Jim Trierweiler, was astounded to see how involved Peter's classmates were in his presentation, asking good questions like, "If we keep up like this, when will the fish be all gone?" The teacher realized he did not have to wait to learn system dynamics before teaching it; he could learn along with the kids. You may not always get such an enthusiastic response, but every little bit helps, and the real benefit is sharing these skills with your own children.

System Dynamics Training

This is a crucial Öed. Because system dynamics is new to everyone, everyone needs training. The quality of their training determines how well and how long teachers will continue to learn and teach using the systems tools. It also determines how this change in education will be perceived by the broader public, especially if the quality of the instruction is diluted by inadequate training. Teachers who have begun using systems tools are always looking for more training and support, and school funds are always tight. System dynamicists and academics can get involved in training, while others can contribute funds for professional development.

The mental model on training has changed over the years. At first the push was to teach everybody how to build computer models right away and to do so in intensive one-week workshops. This was pushing too hard, and the system pushed back. Although the "blitz" approach, with its emphasis on model-building, suited a few teachers, most found it confusing and overwhelming. It was difficult for teachers to continue on their own back at school, so they didn't.

System dynamics, a very big idea, is not quick and easy to learn. It takes time, patience, good instruction and follow-up support. Systems education also involves much more than model-building. Faith Waters believes that training should begin with behavior over time graphs, causal loops, and stock/flow diagrams. Teachers should learn how to use these tools in their curriculum before moving to models. Jeff Potash and John Heinbokel at the Waters Center for System Dynamics at Trinity College of Vermont in Burlington add that before actually building models, teachers should see how models apply to the curriculum, play with little models, and learn about generic structures and transferability. George Richardson of the Rockefeller College of Public Affairs and Policy at the University at Albany, New York cautions that teachers can get discouraged and feel inadequate or incompetent if they think that they are supposed to be able to build models right away.

Although all agree that the most powerful learning comes from building and using your own models, for teachers and students alike, it is not realistic to expect that everyone will get to that level, and certainly not immediately. We certainly need teachers with good modeling skills, but at this very early stage in systems education, pushing too hard at first will turn many fine teachers away. Supporting them at their own pace lets them proceed further (or choose not to). In other words, there is a big gap between the level of system dynamics skills we need and the current level. This applies to individual teachers as well as to the education system as a whole. As we aim for the higher goal, we need to remember that the accumulation of skills takes time.

Training also involves more that just learning the basics of system dynamics. The other essential piece is pedagogy: How do you actually teach these skills and perspectives to children? Teachers are the experts in this realm. Mary Scheetz adds, "Just like the basics of math or reading, it takes a great deal of skill to teach the basic concepts of anything, to begin to build the infrastructure that it will take to acquire higher level skills." Teachers need time and support to work together to develop their own best teaching strategies for their students. They also need time to determine how to present systems skills in a progression that is developmentally appropriate for students. Finally, they need to devise assessment techniques. Teachers learn these things from one another, with time to work together.

There are several possibilities for training. Teachers benefit most from training if they work in teams so that they can support one another's learning during the training and later in the classroom.

- The Waters Foundation has supported the development of several training opportunities by Jeff Potash and John Heinbokel of the Waters Center for System Dynamics. Jeff and John structure their training to help students progress on their own learning curves through increasing levels of authorship and curriculum integration. Their advice, based on experience, is not to rush the process. Their programs include:
  - "Modeling Systems Self-Taught" (MSST), a self-paced tutorial, part of which is available free.
  - A five-course Graduate Certificate in System Dynamics for Educators, parts of which can be delivered over the Internet.
  - Week-long summer training sessions for educators, some of which contribute to the Graduate Certificate.

Suggestions *continued on page 11*

Materials Now Available from the CLE at www.clexchange.org

SYSTEMS EDUCATION

SE2000-10Pioneer5-WhyRush **What It's Like to Be a Pioneer: What's the Rush?** Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Another vignette in the "Pioneer" series. [Systems Education, Elementary School, Middle School, High School, K-Adult] ($1.00)

SE2000-10Pioneer6-Expert **What It's Like to Be a Pioneer: Working with an Expert.** Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Another vignette in the "Pioneer" series. [Systems Education, Elementary School, Middle School, High School, K-Adult] ($1.00)

SE2000-10Pioneer7-Naturally **What It's Like to Be a Pioneer: Interedisciplinary, Naturally.** Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Another vignette in the "Pioneer" series. [Systems Education, Elementary School, Middle School, High School, K-Adult] ($1.00)

CROSS CURRICULAR

CC2000-10GraphFriendshipGame **Graphing the Friendship Game: A Preliminary System Dynamics Lesson.** Alan Ticotsky with Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund.A variation on the original Friendship Game (SS1996-11FriendshipGame) becomes the foundation for an introductory graphing lesson for students in grades K- 2, adding graphing to the systems tools used and systems concepts learned in the game. [Cross Curricular, Social Studies, System Dynamics, Behavior over Time Graphs, Causal Loops, Math, Elementary School] ($1.00)

CC2000-10NewspaperPart1 **Create and Run Your Own Newspaper: A Journalism Unit with a Simulation Game Part 1: Publish a Newspaper.** Daniel Barcan, Leah Zuckerman, Gary Hirsch , and Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Part 1 of a 3 part series. In this interdisciplinary language arts and social studies journalism unit, middle schoolers write articles and create their own newspapers. [Cross Curricular, English, Social Studies, Simulation, Middle School, High School] ($1.00)

CC2000-10NewspaperPart2 **Create and Run Your Own Newspaper: A Journalism Unit with a Simulation Game Part 2: Play the Game.** Daniel Barcan, Leah Zuckerman, Gary Hirsch, and Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Part 2 of a 3 part series. In this second part of a three-part journalism unit, students become newspaper owners and try to run their own successful businesses in a simulation game. The game is a system dynamics management flight simulator, a realistic model of a newspaper business which students run by making their own policy decisions on quality, hiring, firing, and pricing. [Cross Curricular, English, Social Studies, Behavior over Time Graphs, Simulation, Dynamic Modeling, Middle School, High School] ($1.00 paper only; $6.00 paper + model on disk)

CC2000-10NewspaperPart3 **Create and Run Your Own Newspaper: A Journalism Unit with a Simulation Game Part 3: Examine the Model.** Daniel Barcan, Leah Zuckerman, Gary Hirsch, and Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Part 3 of a 3 part series. In this last part of a three-part journalism unit, students and teachers can take a closer look at the system dynamics model underlying the management flight simulator game from Part 2. There is a brief explanation of the model in simple terms, followed by a series of activities using the model as a laboratory. [Cross Curricular, English, Social Studies, System Dynamics, Simulation, Dynamic Modeling, Middle School, High School] ($1.00 paper only; $6.00 paper + model on disk)

ENGLISH

EN2000-10TuckEverlasting **Tuck Everlasting: System Dynamics, Literature, and Living Forever.** Carolyn Platt, Rob Quaden and Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. Sixth grade students use system dynamics tools to explore themes in the novel "Tuck Everlasting," by Natalie Babbitt. After reading the novel, students use behavior over time graphs and a simple system dynamics computer model to discuss their opinions on the story's major themes. [English, Behavior over Time Graphs, Dynamic Modeling, Middle School] ($1.00)

MATH

MA2000-10GraphingSkills **Drawing and Reading Behavior over Time Graphs: Four Math Lessons to Build Graphing Skills.** Rob Quaden with Debra Lyneis

Prepared with the support of the Gordon Stanley Brown Fund. In this series of exercises, eighth grade math students learn how to read and interpret graphs, to draw graphs to specify their ideas and explain them to others, and develop the skills of thinking and communicating in terms of graphs. [Math, Behavior over Time Graphs, Middle School] ($1.00)

Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 9

The Waters Center has been located at Trinity College in Burlington, VT, but is currently in an uncertain situation, as Trinity College is in the process of closing. Check the Center's web site, http://trinityvt.edu/waters, or contact the Creative Learning Exchange for the current status of the Center and its programs.

- High Performance Systems regularly presents STELLA training sessions across the country. *An Introduction to Systems Thinking*, which accompanies the software, is an excellent introduction to the broad ideas of systems thinking as well as the mechanics of system dynamics. STELLA also includes a tutorial. Visit their website at http://hps-inc.com.

- The National Science Foundation (NSF) funded a very large teacher training program in Portland, Oregon, Cross-Curricular Systems Thinking and Dynamics Using STELLA (CC-STADUS), from 1993 to 1997. The investigators were Diana Fisher, Ed Gallaher and Ron Zaraza. A smaller grant was extended until 2000. Teachers worked in interdisciplinary teams to learn modeling and develop lessons. They had follow-up guidance during the year to implement their lessons. Many teachers and students benefited from this program. Although the training is no longer available, it serves as a model for others. Diana has written about the training in *Mistakes Made in the Early Years Teaching Students and Teachers to Create System Models*. It is available (SE1998-10) on the CLE list of Systems Education materials (http://www.clexchange.org). There are many other excellent articles and materials from CC-STADUS on the CLE lists. Check also the Portland schools' website: http://www.CC-STADUS.com.

- The System Dynamics in Education Project at MIT, under the supervision of Jay Forrester, has produced *Road Maps*, a guided self-study of system dynamics, available free from the website, http://sysdyn.mit.edu. This is a very good series of lessons on the theory and practice of system dynamics. You could work through *Road Maps* with a group of teachers, if you have teachers who are ready to step beyond the beginning level of system dynamics. *Road Maps* is time-consuming and challenging. It is also not directly related to K-12 curriculum applications, so teachers may not see its relevance at first. For teachers who have reached the need to advance their own skills, however, it is excellent. A slow sustainable pace is better than a rapid start that falters (a lesson learned the hard way in Carlisle.) Time is always an issue. A donation of funds for a teacher's release time—paying for a substitute teacher's time—or a summer stipend to work on this would be very helpful.

- A step beyond a *Road Maps* study group is the MIT SDEP Guided Study Program, a distance learning program conducted via e-mail (at http://sysdyn.mit.edu). The program runs from September to June and covers *Road Maps* with additional readings and weekly assignments. Each participant works with an MIT student tutor supervised by Jay Forrester. This program requires a commitment of at least fifteen hours a week . If your school has an advanced teacher ready for this, find a way to support part of that teacher's salary for a year to make time for this professional development. That teacher would then become a skilled resource for the school.

- Because K-12 systems education is still very new, there are not many organized training opportunities for teachers. System dynamics is taught in some business, public policy and engineering schools (see "Studying System Dynamics" at http://sysdyn.mit.edu), but it needs to move into schools of education also. Lesley College (http://lesley.edu) offers a technology in education course, "Microworlds, Models, and Simulations," which includes system dynamics. See if your local college has system dynamics course offerings for teachers. If not, express the need, and urge other teachers to do the same.

- Probably the single most effective training arrangement is the use of systems mentors in schools. Rob Quaden and Alan Ticotsky are Carlisle's mentors supported by the Waters Foundation. For their own training they attended Waters and NSF sessions and they are working through *Road Maps*. Their job is to help other teachers find ways to enhance their current curriculum using behavior over time graphs, causal loops, stock/flow diagrams, modeling, and games. At first they might actually teach the systems lesson in another teacher's class until that teacher is ready to go solo, however long that takes. They also give in-service workshops and presentations to the public. Business was slow at first, but now they are in heavier demand as more teachers see successful lessons and want to try them with their students. Rob taught system dynamics in his math classes for several years before becoming a mentor. He sees the mentoring program as a very high-leverage way to involve more teachers.

  - Will Glass-Husain, an MIT SDEP graduate, was an early mentor in Tucson. His paper, *Lessons for System Dynamics Mentors in Schools*, explains "how" and "why." (The paper is available at http://www.clexchange.org, on the list of Systems Education materials—SE1995-05LessonsForMentors.)

  - Mentors are expensive. Schools need support for the cost of a teacher salary—or two, because mentors work best in teams. However, this is a very high-leverage contribution to spread and sustain systems education.

***Suggestions** continued on page 12*

Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 11

System Dynamics Expertise

Professional system dynamicists have a vital role to play in quality-control; it is so important that what teachers are learning and teaching is correct. However, George Richardson, who has been advising and training systems mentors, cautions outsiders, particularly professional system dynamicists who are not used to teaching teachers about "…how to behave in helping teachers. The first pitfall is presuming to know what they need and telling them. The proper initial behavior is listening—observing teachers and their kids, if possible—listening for a long time. This period serves two crucial purposes; building trust and building understanding."

- Offer to review lessons and models to help teachers teach correct system dynamics. Teachers recognize this need, but be tactful in your approach.
- Offer to coach students who are working on independent system dynamics projects.
- Offer to work with a teacher to develop a model that is relevant to the curriculum. Gary Hirsch, a professional system dynamicist and management consultant from Wayland, Massachusetts offered his services to the Chelmsford Public Charter School, which has system dynamics written into its charter. At first he taught system dynamics to students directly, but it proved a better use of his time and expertise to work with two teachers to build a management flight simulator for a current journalism unit. Together, they built a model on which students could realistically run their own newspaper businesses. Dan Barcan and Leah Zuckerman learned model-building from an expert and produced a sophisticated model to use with their students. ("Create and Run Your Own Newspaper," will be posted on the CLE website.) Gary and Dan advise others to work out the best way to efficiently combine the teacher's classroom expertise with the modeler's system dynamics expertise.
- Use a model. Gary Hirsch built another very interesting model. Working with Jay Forrester, education reformer Ted Sizer, and others, Gary built a model exploring how innovation begins and grows in schools. He used the model to test various strategies. Trust between the school and the community appears to be an important variable as are teacher motivation, professional development, and competing initiatives. The feedback system is complex. Results suggest careful planning for innovation and replacing the traditional curriculum with new material and methods rather than piling on extra work. The model also shows the potential value of using system dynamics to examine school problems. The model is on-line at the CLE website, #SE1998-04, "Innovation in Schools: A Model to Help Structure the Discussion and Guide the Search for Strategies."
- Offer to be a system dynamics resource for your school. Jim Lyneis has been a big help in Carlisle. Jim helps teachers build models and explains issues as they come up. He does not need to be at school often, but it reassures mentors to know that, when they have a question, they can get a straight, accurate answer from Jim. Many schools could benefit from the quality control of an expert system dynamicist.

Equipment

This is an urgent need that is essentially uncomplicated: Teachers need up-to-date working computers and software to teach model-building to their students. With tight budgets in schools everywhere, few schools have the resources to purchase, maintain, and replace enough computers to do the job right. Teachers in the field say they have to divert too much teaching time to scrounging, moving, and fixing computers. Any contributions are deeply appreciated.

- Donate however many computers you can. If possible find enough computers for one class. The ideal set-up is to have two students work together building models because they can learn from one another and each get a turn at the keyboard. One suggestion is to have the computers mounted on carts so that they can be wheeled to other classrooms. Another is to also make computers available for teachers to take home, since there is little time during the school day for them to build their own skills and develop lessons.
- Donate a computer projection device. Often a teacher can teach modeling to a whole class using one computer with a projection device. A donated Proxima is in constant use in Carlisle. The mentors use it to explain a model before letting students build their own, or they use it to build or use a model as a class.
- Donate used equipment—but only *if it is current and working*. Schools do not have the skills or resources to make use of broken or obsolete equipment. If possible, set up the donated computers to be sure they are complete and functioning properly.
- Donate system dynamics software. Most schools use STELLA by High Performance Systems (http://www.hps-inc.com). Vensim, by Ventana Systems, is also used in some schools (http://www.vensim.com). A site license allows the school much wider use and flexibility.
- Offer technical assistance. This would be a godsend for most schools. One business loaned a computer employee to a school for one afternoon a week to work on software and hardware glitches.

- Remember that computers wear out with heavy use by kids and need to be regularly replaced—a big budgetary problem for most schools.
- While good computers will not insure systems education in a school, systems education cannot proceed very far without them.

Community Education

Anyone can participate in this. Very early on in Carlisle we got wise counsel from Jim Waters: "Don't get too far ahead of your taxpayers on this." Gordon Brown wrote in the *System Dynamics Review*, "The patrons of public education are the taxpayers, and they must be kept informed."(CLE website, #1993-01ImprovingEducation) They are right, of course, but it is easy to forget this when you are absorbed within a school. The systems approach is a big change in education. It is prudent to keep community members informed so that they can learn from you while you also learn from them. There are many ways to do this.

- Write articles for the local newspaper explaining what students are doing using this approach. Use photos and quotes from kids. Do this often.
- Support the school whenever it presents the topic at a parents' meeting, school board meeting, back-to-school night, etc. Attend these functions, ask questions, and say nice things. This may seem trivial, but it is actually very influential.
- Help students use their skills on a local problem. Larry Weathers' high school students from Harvard, Massachusetts met with town selectmen and finance board members to build a small model of the town budgeting process and how the level of trust affects the outcome: You actually need a just little bit of distrust on both sides to get the best results!
- Facilitate ways to help kids celebrate and showcase their work to both acknowledge them and raise public awareness in your community. In Portland, Oregon high school students participate in SyMBowl, an annual regional exposition of their system dynamics work. Ed Gallaher, who uses system dynamics in his work as a professor of pharmacology and behavioral neuroscience at Oregon Health Sciences University in Portland, started SyMBowl in 1996. Participation has grown steadily; this year the Oregon Museum of Science and Industry hosted SyMBowl in their new building, increasing its visibility, prestige, participation, and attendance. The student projects are impressive! Read a few for inspiration. Find a way for your students to attend, or contact Ed Gallaher about organizing your own SyMBowl. (A similar exposition was launched this year in the northeast. Initiated by teacher Will Costello, DynamiQueST was held at Trinity College of Vermont in Spring 2000. Find details on the CLE website, http://www.clexchange.org)
- Help recruit local experts to advise students on their projects. Students build models of real world problems, but they cannot always find the precise information they need. It is wonderful if they can consult people who are actually involved in the field. Townspeople are always impressed with the depth of the students' questions.
- Help teachers write-up their curriculum ideas for publication. This helps teachers refine their ideas and chronicles their progress. It also shares their work with the community and other teachers. I have had the privilege of doing this through the Gordon Brown Fund. It is fun. See the CLE website for examples of these lessons as well as a series of articles on "what it's like to be a pioneer."
- Endorse any way at all to increase the communication between your school and your community. Keep taxpayers informed and involved; listen to their concerns and advice. In Carlisle, Davida Fox-Melanson began the Carlisle Education Forum, an annual Saturday morning town event where townspeople are invited to hear a speaker and share their ideas with neighbors and school staff about education for the future. Townspeople say they appreciate the chance to learn about education and have their say. Meanwhile, the school benefits from their feedback. Years ago, Peter Senge and Jay Forrester were our honored guests. In breakout discussions, townspeople agreed that education needed to improve, but they were leery of rash changes. Their advice on system dynamics: "Go for it, but keep us informed and don't ignore the basics."
- Welcome citizen involvement, especially among folks who do not have children in school. After one forum, Carlisle resident Neils Larsen stepped forward. Neils was a retired executive who had studied system dynamics years ago. He quietly observed classes and was impressed watching students use a model in a science experiment. Neils helped the school board by facilitating the articulation of our vision and goals. He also lined up our next forum speaker. His quiet encouragement, at a time when we felt we were getting nowhere, was invaluable.

Lobbying, Political Support, Encouragement

If the best gifts are free, this is a good example. Anyone can offer this support. It is priceless and essential.

- If your child's teacher uses systems tools, give that teacher some positive feedback. Tell the teacher what your child has learned. Teachers need your encouragement. One Carlisle teacher was so pleased to hear that her first grader had drawn a behavior over time graph for his dad on a restaurant napkin!

Suggestions *continued on page 14*

Suggestions for Introducing and Sustaining SD in K-12 Education

continued from page 13

- Tell teachers if you use systems tools in your job. Teachers like to know that what they are teaching will be useful to their students in the future.

- Lobby school building and district administrators. Commend a teacher's good work. Tell administrators you'd like to see more systems education and offer to help. It means a great deal to teachers and administrators when you notice and commend good work. This is very influential.

- School boards are important to lobby too. Everyone knows that a few vocal, negative parents can get school board attention, but a few positive, supportive parents with a convincing position can be even more powerful. As elected officials, school board members are interested in your views, and most of them run for office because they have a commitment to improving their schools. School boards cannot/should not micromanage their schools, but they do set policy and budgets. Lobby them; better yet, run for office yourself!

- Help address political opposition. Any change in education will have its opponents, and this is no exception. Gordon Brown met tirelessly and respectfully with vocal parents opposed to change in Tucson. Some parents fear any departure from their own familiar education. Others suspect that learner-centered-learning means lazy teaching. (See "Politics and the Lazy Teacher" on the CLE website, SE1999-04Pioneer2-LazyTeach.) While some reluctant parents can be assuaged and convinced, the rest, in Jay Forrester's words, "we will just have to outlive." (This also applies to teachers. A few will be eager pioneers, many will be open to the idea of change to varying degrees, and some will be wholly resistant to change. Focus your positive energies on the first two groups, without antagonizing the third.)

- Work together as parents. In Chelmsford, Massachusetts a group of parents organized to start their own charter school when previous lobbying attempts to change the structure of their traditional junior high school did not succeed. They founded the Murdoch Middle School, Public Charter School of Chelmsford, MA and wrote system dynamics into its charter. Bravo! Sue Jamback is the school's director.

- Request systems training programs at local colleges. Ask local businesses to help out with computers. Talk to your neighbors. Without becoming an overbearing pest, or a preacher for a cause, put in a judicious good word whenever the opportunity arises.

Business Involvement

When businesses get involved in education, they improve their reputation in the community while also providing better-educated employees. Involvement is good for business and good for schools.

- A fine example is the active participation of Portland General Electric in introducing system dynamics in the Portland, Oregon schools. Richard Turnock was hired by PGE to support education services outreach for technology initiatives in schools. He became interested in systems thinking when he took a PGE sponsored "Change Tools for Educators" based on the *Fifth Discipline*. He also attended SyMBowl and a Portland NSF summer training session. He was "hooked." Now PGE has an extensive program in support of system dynamics in Portland's schools. It offers two continuing education courses for graduate credit through Portland State University, it supports SyMBowl, it donates computer equipment and STELLA site licenses to schools, and it encourages PGE employees to volunteer in schools. Richard explains the PGE program and why systems education is good for children at http://www.pge-edsucs.com. He believes other businesses could do the same.

- Another example is the involvement of Georgia Pacific in the early introduction of system dynamics to the Glynn County School System in rural coastal Georgia. As recounted by mentor Jan Mons, Georgia Pacific wanted to give the county an innovative science/math program "to teach students to think." After much research, they chose system dynamics, which in 1991 was very new to K-12 education. They purchased computers, outfitted computer labs, and hired Barry Richmond of High Performance Systems to train nine teachers and nine of their own engineers, with the goal of applying system dynamics to the schools, the workplace, and the community. Unfortunately, what started out as a five-year commitment was cut short when the business climate changed and the manager was transferred. Although this was a difficult transition for the teachers, somehow the system dynamics stuck, and now the program is back on its feet and growing with the support of the Waters Foundation. Lessons learned from these early pioneers:

  - Georgia Pacific got involved for all the right reasons;
  - It would be better not to have an exclusive group of "chosen" teachers given release time to develop lessons, because this can create resentment;
  - It would be better to help teachers develop and accept their own curriculum changes rather than to impose them from the top through the select teachers;
  - It would be better to approach teachers asking them what they need rather than treating system dynamics as a "great product to sell;"
  - The folks in Georgia have worked hard to learn from early mistakes and succeed.

- Jay Forrester sees a golden opportunity for corporate participation in systems education. Big corporations make large donations to education, usually supporting programs which are already in place, in effect, inadvertently doing more of what is already causing problems within the current education system. Instead, corporations could direct their resources to fundamental change in education. Forrester sees this as a job for a recently retired, energetic, knowledgeable, and effective executive who wants to do something important. This would be a person with the time and inclination to learn about system dynamics in education and network with other corporate executives to slowly build their support. It would take some freewheeling, quiet persistence and an understanding based on business experience that success does not follow a straight easy path. Patience would be the biggest challenge because, even backed with lots of money, systems education will not take root if it is imposed from the top as the "latest thing" and pushed with "yesterday" deadlines. However, this is a great opportunity for someone to get involved and make a very meaningful contribution to a worthy and exciting cause.

"Education investors" Jim and Faith Waters set just the right example for how to change schools in the long run, on a large scale. Jim calls it "successive approximation"—taking small steps toward a goal, evaluating each step along the way, and planning the next move, all with lots of patience. It is a recursive process; long-term improvements take time. Faith calls it "benign neglect, with responsibility"—allowing teachers to experiment while providing careful oversight and high expectations. They would advise granting money only to schools that have demonstrated prior commitment to a process that is a great deal of work. (One principal approached them saying, "I don't care what it is, as long as it has funding, we'll do it!" Not likely a good investment!) Mary Scheetz believes the Waters' biggest contribution has been their trust—trust that teachers are trying to do "the good and right thing," but that they need to experiment and learn from mistakes in order to continue to improve.

Time

How much time will it take? Jim and Faith Waters think that it takes at least 7 to 10 years for the systems approach to become embedded in a school's curriculum, culture and management. Jay Forrester adds that we will not begin to see real change until young students in today's pioneering schools become teachers themselves. Educators involved in the process believe that this change is inexorable as schools adapt to the changing needs of a dynamically complex global economy. However, although widespread change may be distant, every small contribution today begins to benefit some students right away.

WHAT DO YOU GET IN RETURN?

Much of this paper has focussed on how to get involved, with less emphasis on why. Many people have made these contributions and will continue to do so. They invite you to join them. Besides the enjoyment of working with a network of wonderful dedicated people, what are the returns?

- First, you improve education for children by reinforcing every child's natural drive to learn, rather than stultifying it. Children love to dig in and learn for themselves. Systems education offers them that opportunity and there is great joy in being a part of it. It is like teaching children to ride a bike. You can provide the bikes and run beside them, but they have to learn on their own. No matter how much they fall, they persevere until they get it. Then, they are off! Education could be like that.
- Second, when you become involved in your community's school, you gain a deeper appreciation of the challenges in education and the commitment of the many fine educators who work hard to meet them. Seeing the strengths of the current system, you also get a more realistic view of how to work together to address its weaknesses. Everyone benefits when the school and the community work together to improve education.
- Finally, system dynamics and systems thinking give students the skills and perspectives they will need to understand and effectively deal with dynamic complexity. Systems education can teach them to:
- Recognize feedback systems around them: flows, accumulations, delays, interdependency, and change.
- Know that cause is often removed from effect in time and space.
- Understand the difference between long and short-term consequences, and the inevitability of trade-offs.
- Understand that addressing symptoms does not solve problems.
- Use system dynamics to clarify mental models, communicate ideas clearly, and make more informed decisions about a wide range of issues.
- Accept with responsibility and courage that what they do makes a difference.

These are big returns on any investment of time, energy, money, and support.

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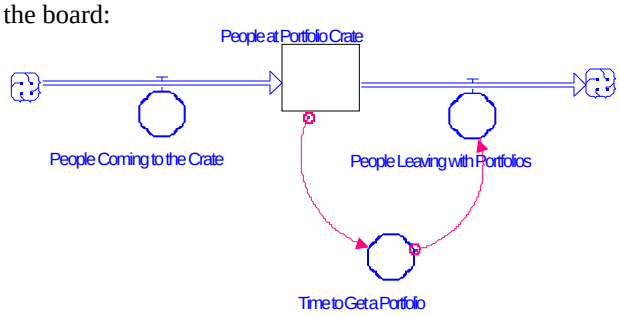
WHAT'S THE RUSH? continued from page 1

their files more systematically, Dan tried the usual classroom management tricks like repeatedly reminding students to be more orderly and appointing student monitors. Nothing made much difference. Then, one day when the students were crowded around the crate making especially slow progress getting their folders, Dan called a time-out. He quickly led students through a discussion that produced this stock/flow diagram on the board:



The stock is the number of people crowded at the crate. People approach the crate and leave with their portfolios, but in this class it had not been a smooth flow in and out. Why not? The students figured out that the time to get a portfolio is longer when there are more people crowded around the crate. It is harder to find a folder and get out of the way with everybody pushing in at the same time. In trying to get their own folders as quickly as possible, students were actually making the whole process go more slowly. This class discussion took just two minutes.

It must have made sense to the students because right away they devised a better way to get their portfolios. Some students stepped aside to let others go by. Others waited at their seats while friends picked up their folders for them. Without much confusion, they efficiently got their portfolios and got down to work. Dan was impressed.

The proof of the lesson came several days later, however. The students were seated together in an all-school assembly. When the assembly ended, most students crowded the exit as usual. Expecting to see his students do the same thing, Dan turned to see them seated patiently instead. "What's the rush?" they said smugly. "We can get out faster if we just sit here and relax until everyone else clears out of the way!" Smart kids!

These students were able to use a basic system dynamics understanding to solve a real-life problem on their own. Furthermore, they could transfer that understand-ing to another similar problem. Previous directives from the teacher had not sunk in. As Dan says, "Nothing that I had done which was just language-based had let them see the connection between what they did and what happened." The stock/flow diagram helped them make that connection and use it.

Granted, these students had some prior experience with system dynamics modeling and stock/flow diagrams, but it seems reasonable to expect that other students could also use these tools to understand and solve real-life problems once they have seen how things work.

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