System Dynamics and Learner-Centered-Learning in Kindergarten through 12th Grade Education

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***Abstract**: Pre-college education is under attack for poorly serving the needs of society. Unless a superior concept for improving education emerges, public displeasure is apt to result in still more of what is already not working. But now, a fundamentally new and more effective approach to education is emerging from advances in system dynamics. System dynamics offers a framework for giving cohesion, meaning, and motivation to education at all levels from kindergarten upward. A second important ingredient, "learner-centered learning," imports to pre-college education the challenge and excitement of a research laboratory. Together, these two innovations harness the creativity, curiosity, and energy of young people. System dynamics allows reversing the traditional educational sequence in which deadening years of learning facts have preceded use of those facts by introducing synthesis (putting it all together) at an early stage in a student's experience. Such synthesis can be based on facts that even elementary school students already have gleaned from life. Learner-centered learning reverses the process of a teacher lecturing facts to resistant students. Learners have the opportunity to explore, gather information, and create unity out of their educational experiences. A "teacher" in the new setting acts as a guide and participating learner, rather than as an authoritarian source of all wisdom.*

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Secondary education is under increasing attack for not preparing students to cope with modern life. Failures appear in the form of corporate executives who misjudge the complexities of growth and competition, government leaders who are at a loss to understand economic and political change, and publics that support inappropriate responses to immigration pressures, changing international conditions, rising unemployment, the drug culture, governmental reform, and inadequacies in education.

Growing criticism of education may direct attention to incorrect diagnoses and ineffective treatments. Weakness in education arises not so much from poor teachers as from inappropriateness of material that is being taught. Students are stuffed with facts without having a frame of reference for making those facts relevant to the complexities of life. Responses to educational deficiencies are apt to result in public demands for still more of what is causing the present educational failures. Pressures will increase for additional science, humanities, and social studies in an already overcrowded curriculum, a curriculum that fails to instill enthusiasm and a sense of relevance. Instead, an opportunity exists for moving toward a common foundation that pulls all fields of study into a more understandable unity.

1. Sources of Educational Ineffectiveness

Much current dissatisfaction with pre-college education arises from past inability to show how people interact with one another and with their physical environment, and to reveal causes for what students see happening. Because of its fragmentary nature, traditional education becomes less relevant as society becomes more complex, crowded, and tightly interconnected.

Education is compartmentalized into separate subjects that, in the real world, interact with one another. Social studies, physical science, biology, and other subjects are taught as if they were inherently different from one another, even though behavior in each rests on the same underlying concepts. For example, the dynamic structure that causes a pendulum to swing is the same as the core structure that causes employment and inventories to fluctuate in a product-distribution system and in economic business cycles. Humanities are taught without relating the dynamic sweep of history to similar behaviors on a shorter time scale that a student can experience in a week or a year.

High schools teach a curriculum from which students are expected to synthesize a perspective and framework for understanding their social and physical environments. But that framework is never explicitly taught. Students are expected to create a unity from the fragments of educational experiences, even though their teachers have seldom achieved that unity.

Missing from most education is direct treatment of the time dimension. What causes change from the past to the present and the present into the future? How do present decisions determine the future toward which we are moving? How are lessons of history to be interpreted to the present? Why are so many corporate, national, and personal decisions ineffective in achieving intended objectives? Conventional educational programs seldom reveal the answers. Answers to such questions about how things change through time lie in the dynamic behavior of social, personal, and physical systems. Dynamic behavior, common to all systems, can be taught as such. It can be understood.

Education has taught static snapshots of the real world. But the world's problems are dynamic. The human mind grasps pictures, maps, and static relationships in a wonderfully effective way. But in systems of interacting components that change through time, the human mind is a poor simulator of behavior. Mathematically speaking, even a simple social system can represent a tenth-order, highly nonlinear, differential equation. Mathematicians can not solve the general case for such an equation. No scientist, citizen, manager, or politician can reliably judge such complexity by intuition. Yet, even a junior high school student with a personal computer and coaching in computer simulation can advance remarkably far in understanding such systems.

Education faces the challenge of undoing and reversing much that people learn by observing simple dynamic situations. Experiences in everyday life deeply ingrain lessons that are deceptively misleading when one encounters more complex social systems (Forrester, 1971). For example, from burning one’s fingers on a hot stove, one learns that cause and effect are closely related in both time and space. Fingers are burned here and now when too close to the stove.

Almost all understandable experiences reinforce the belief that causes are closely and obviously related to consequences. But in more complex systems, the cause of a difficulty is usually far distant in both time and space. The cause originated much earlier and arose from a different part of the system from where the symptoms appear.

To make matters even more misleading, a complex feedback system usually presents what we have come to expect, an apparent cause that lies close in time and space to the symptom. However, that apparent cause is usually a coincident symptom through which little leverage exists for producing improvement. Education does little to prepare students for succeeding when simple, understandable lessons so often point in exactly the wrong direction in the complex real world.

2. Cornerstones for a More Effective Education

Two mutually reinforcing developments now promise a learning process that can enhance breadth, depth, and insight in education. These two are system dynamics and learner-centered learning.

2.1. Precursors of System Dynamics

System dynamics evolved from prior work in feedback-control systems. The history of engineering servomechanisms reaches back several hundred years. Popular writing, religious literature, and the social sciences have grappled with the closed-loop circular nature of cause and effect for thousands of years (Richardson, 1991). In the 1920s and 1930s, understanding the dynamics of control systems accelerated. New theory evolved during development of electronic feedback amplifiers for transcontinental telephone systems at the Bell Telephone Laboratories and work at MIT on feedback controls for analog computers and military equipment.

After 1950, people became more aware that feedback control applies not only to engineering systems but also to all processes of change—biological, natural, environmental, and social.

2.2. System Dynamics in Pre-College Education

During the last 30 years, those in the profession of system dynamics have been building a more effective basis than previously existed for understanding change and complexity. The field rests on three foundations:

1. Growing knowledge of how feedback loops, containing information flows, decision making, and action, control change in all systems. Feedback processes determine stability, goal seeking, stagnation, decline, and growth. Feedback systems surround us in everything we do. A feedback process exists when action affects the condition of a system and that changed condition affects future action. Human interactions, home life, politics, management processes, environmental changes, and biological activity all operate on the basis of feedback loops that connect action to result to future action.

2. Digital computers, now primarily personal computers, to simulate the behavior of systems that are too complex to attack with conventional mathematics, verbal descriptions, or graphical methods. High school students, using today's computers, can deal with concepts and dynamic behavior that only a few years ago were restricted to work in advanced research laboratories. Excellent user-friendly software is now available (High Performance Systems, 1990; Pugh, 1986).[1]

3. Realization that most of the world's knowledge about dynamic structures resides in people's heads. The social sciences have relied too much on measured data. As a consequence, academic studies have failed to make adequate use of the data base on which the world runs—the information gained from living experience, apprenticeship, and participation. Students, even as early as kindergarten, already have a vast amount of operating information about individuals, families, communities, and schools from which they can learn about social, business, economic, and environmental behavior.

The system dynamics approach has been successfully applied to behavior in corporations, internal medicine, fisheries, psychiatry, energy supply and pricing, economic behavior, urban growth and decay, environmental stresses, population growth and aging, training of managers, and education of primary and secondary school students.

Nancy Roberts first demonstrated system dynamics as an organizing framework at the fifth and sixth grade levels (Roberts, 1975). Her work (Roberts, 1978) showed the advantage of reversing the traditional educational sequence that normally progresses through five steps:

1) learning facts
2) comprehending meaning

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[1] For most work at the pre-college level, STELLA™ on Macintosh computers is easiest to use. It includes an excellent manual with learning exercises and an introduction to the philosophy of system dynamics. Some other system dynamics software packages are being developed with special attention to use in secondary schools. For more advanced professional use, software exists for system dynamics modeling, such as DYNAMO™ from Pugh-Roberts and Vensim™ from Ventana Systems.

3) applying facts to generalizations
4) analyzing to break material into constituent parts
5) synthesizing to assemble parts into a whole.

Most students never reach that fifth step of synthesis. But, synthesis—putting it all together—should be placed at the beginning of the educational sequence. By the time students are in school they already possess a wealth of observations about family, interpersonal relations, community, and school. They are ready for a framework into which the facts can be fitted. Unless that framework exists, teaching still more facts loses significance.

In his penetrating discussion of the learning process, Bruner states, "the most basic thing that can be said about human memory… is that unless detail is placed into a structured pattern, it is rapidly forgotten" (Bruner, 1963, p. 24). For most purposes, such a structure is inadequate if it is only a static framework. The structure should show the dynamic significance of the detail—how the details are connected, how they influence one another, and how past behavior and future outcomes arise from decision-making policies and their interconnections.

System dynamics can provide that dynamic framework to give meaning to detailed facts. Such a dynamic framework provides a common foundation beneath mathematics, physical science, social studies, biology, history, and even literature.

In spite of the potential power of system dynamics, it could well be ineffective if introduced alone into a traditional educational setting in which students passively receive lectures. System dynamics can not be acquired as a spectator sport any more than one can become a good basketball player by merely watching games. Active participation instills the dynamic paradigm. Hands-on involvement is essential to internalizing the ideas and establishing them in one's own mental models. But traditional class rooms lack the intense involvement so essential for deep learning.

2.3. Learner-Centered Learning

Those who have experienced the excitement and intensity of a research laboratory know the involvement accompanying new discoveries. Why should not students in their formative years experience similar exhilaration from exploring new challenges? That sense of challenge exists when a classroom operates in a "learner-centered-learning" mode.

Learner-centered learning, is a term I first encountered from Mrs. Kenneth Hayden of Ideals Associated.[2] It substantially alters the role of a teacher. A teacher is no longer a dispenser of knowledge addressed to students as passive receptors. Instead, where small teams of students explore and work together and help one another, a "teacher" becomes a colleague and participating learner. Teachers set directions and introduce opportunities. Teachers act as guides and resource persons, not as authoritarian figures dictating each step of the educational process. The relationship is more like being a thesis adviser than a lecturer.

3. The Gordon Brown Influence

The thread leading to system dynamics started when I was introduced to feedback systems in the early 1940s by Gordon S. Brown, then director of the MIT Servomechanisms Laboratory. Later, Brown became head of the MIT Electrical Engineering Department and then Dean of Engineering before retiring in 1973. In the late 1980s, he completed the circle he had originally launched by picking up system dynamics and introducing it into the Orange Grove Junior High School in Tucson, Arizona (Brown, 1992).

Friends of Brown have established the "Gordon Stanley Brown Fund," administered through the System Dynamics Society. The fund will support released time and summer time for teachers who have applied system dynamics, so that they can put into transmittable and usable form the materials and methods that can help others. It will also support communication of experiences that did not meet expectations so that others can be forewarned of difficulties and paths to be avoided.

Brown describes his role as the "citizen champion" engaged in drawing all participants in the school system together in their search for a new kind of education:

> "the use of computers in the classroom (not in a computer lab) has, for us in Tucson, resulted in a very unique learning environment… (students) learn what they need to know as the teacher guides them in conducting a simulation in class. They work in groups, two or three to a computer—certainly not one per computer—and thereby help one another. Dr. Barry Richmond says that this situation, in effect, multiplies the number of teachers by the number of students.

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[2] Ideals Associated, 2570 Avenida de Maria, Tucson, AZ 85718 USA is a small foundation that for two decades has fostered an approach to learning that enlists students themselves in an active participation that contributes to the momentum of the educational process.

> Before doing a simulation the students spend several class periods gathering information about the topic; they take notes during lectures, learn about a library and read references, and, working as a group, plan the simulation. By working this way Draper's students do not merely try to remember the material for a test but actually have to use it in a project simulating real life situations. This has led us to identify a new teaching paradigm which we define as SYSTEM THINKING with LEARNER-CENTERED LEARNING." (Brown, 1990)

Gordon Brown started by loaning the STELLA software for a weekend to Frank Draper, an 8th grade biology teacher. Draper returned with the comment, “This is what I have always been looking for, I just did not know what it might be.” At first, Draper expected to use system dynamics and computer simulation in one or two classes during a term. Then he found they were becoming a part of every class. With so much time devoted to system dynamics and simulation, he feared he would not have time to cover all the required biology. But, two thirds of the way through the term, Draper found he had completed all the usual biology content. He had a third of the term left for new material. The more rapid pace had resulted from the way biology had become more integrated and from the greater student involvement resulting from the systems viewpoint. Also, much credit goes to the “learner-centered learning” organization of student cooperative study teams within the classroom. To quote Draper, “There is a free lunch.” He writes of his classroom experience:

> "Since October 1988 our classrooms have undergone an amazing transformation. Not only are we covering more material than just the required curriculum, but we are covering it faster (we will be through with the year's curriculum this week and will have to add more material to our curriculum for the remaining 5 weeks) and the students are learning more useful material than ever before. 'Facts' are now anchored to meaning through the dynamic relationships they have with each other. In our classroom students shift from being passive receptacles to being active learners. They are not taught about science per se, but learn how to acquire and use knowledge (scientific and otherwise). Our jobs have shifted from dispensers of information to producers of environments that allow students to learn as much as possible.
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> "We now see students come early to class (even early to school), stay after the bell rings, work through lunch and work at home voluntarily (with no assignment given). When we work on a systems project—even when the students are working on the book research leading up to system work—there are essentially no motivation/discipline problems in our classrooms." (Draper, 1989)

A dynamic framework can even organize the study of literature (Hopkins, 1992) . Classes taught by Pamela Hopkins are from an underprivileged section of the city and many had been labeled as slow learners. Simulation opened the door to a new way of capturing student interest and involvement. In a seminar for teachers taught by Barry Richmond and Steve Peterson of High Performance Systems, she participated in developing a model of psychological dynamics in Shakespeare’s *Hamlet*:

> "(when we used) a STELLA model which analyzed the motivation of Shakespeare's Hamlet to avenge the death of his father in HAMLET… The students were engrossed throughout the process… The amazing thing was that the discussion was completely student dominated. For the first time in the semester, I was not the focal point of the class. I did not have to filter the information from one student back to the rest of the class. They were talking directly to each other about the plot events and about the human responses being stimulated. They talked to each other about how they would have reacted and how the normal person would react. They discussed how previous events and specific personality characteristics would affect the response to each piece of news, and they strove for precision in the values they assigned for the power of each event. My function became that of listening to their viewpoints and entering their decisions into the computer. It was wonderful! It was as though the use of precise numbers to talk about psychological motives and human responses had given them power, had given them a system to communicate with. It had given them something they could handle, something that turned thin air into solid ground. They were directed and in control of learning, instead of my having to force them to keep their attention on the task." (Hopkins, 1990)

Several months after the experience related in the Hopkins article, I received a letter from Louise Hayden, director of Ideals Associated:

> “Pam and I are so pleased and surprised at the ongoing involvement and depth of interest the high school students in her workshop of last June are showing. They are meeting with her weekly after school, eager to learn more about system dynamics and to use their advances to help younger students learn. They are arousing considerable teacher interest as they try to use causal loops in all their class rooms. Information is flowing upward—and from students who varied in achievement from high to very low.
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> We attribute the enthusiasm and commitment to their sense of the potential of systems thinking, and to the feelings of self-worth from being regarded as educational consultants. It is their first experience in learner-centered learning. This may well be the first time they have considered themselves a responsible part of the social system.” (Hayden, 1990)

Many people assume that only the “best” students can adapt to the style of education here suggested. But who are the best students? Results so far indicate no correlation between students who do well in this program and how they had been previously labeled as fast or slow learners. Some of the so-called slow learners find traditional education lacks relevance. They are not challenged. In a different setting they come into their own and become leaders. Some of the students previously identified as best are strong on repeating facts in quizzes but lack an ability to synthesize and to see the meaning of their facts. Past academic record seems not to predict how students respond to this new program.

4. The Present Status

System dynamics is developing rapidly, but does not yet have widespread public visibility. The international System Dynamics Society was formed in 1985. Membership has grown to some 300. Annual international meetings have been held for fifteen years in locations as widely spread as Norway, Colorado, Spain, China, California, Germany, and Thailand. System dynamics books and papers are regularly translated into many languages including Russian, Japanese, and Chinese.

Six hundred people attended a recent conference on systems thinking organized by Pegasus Communications.[3]

After 30 years of development, several dozen books present the theory, concepts, and applications of system dynamics. Some have exerted surprising public impact (Forrester, 1969; Forrester, 1971). *The Limits to Growth* book (Meadows, et al., 1972), showing interplay among population, industrialization, hunger, and pollution, has been translated into some 30 languages and has sold over three million copies. Such wide-spread readership of books based on computer modeling testifies to a public longing to understand how present actions influence the future. *Limits to Growth* has been recently updated as *Beyond the Limits*. (Meadows, et al., 1992)

Early leaders in system dynamics were educated at M.I.T. But competence is now appearing in many places. Talent exists on which to build a new kind of education, even though system dynamics is so broadly applicable throughout physical, social, biological, and political systems that the present small number of experts are thinly dispersed over a wide spectrum of activities.

System dynamics is now becoming well established in some thirty junior and senior high schools. Several hundred schools have started exploratory activity.

Part of the educational emphasis focuses on "generic structures." A rather small number of relatively simple structures appear repeatedly in different businesses, professions, and real-life settings. Students can transfer insights from one setting to another. For example, one of Draper's eighth grade students grew bacteria in a culture dish, then looked at the same pattern of environmentally

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[3] Pegasus Communications, 1696 Massachusetts Ave., Cambridge, MA 02138, publisher of the monthly *The Systems Thinker*.

limited growth through computer simulation. From the computer, the student looked up and observed, “This is the world population problem, isn’t it?” Such transfer of insights from one setting to another will help to break down barriers between disciplines. It means that learning in one field becomes applicable to other fields.

There is now promise of reversing the trend of the last century toward ever greater fragmentation in education. There is real hope of moving back toward the “Renaissance man” idea of a common teachable core of broadly applicable concepts. We can now visualize an integrated, systemic, educational process that is more efficient, more appropriate to a world of increasing complexity, and more supportive of unity in life.

Several high schools, curriculum-development projects, and colleges are using a system dynamics core to build study units in mathematics, science, social studies, and history. But such programs have not yet reached the point of becoming fully integrated educational structures.

The most advanced United States experiment in bringing system dynamics and learner-centered learning together into a more powerful educational environment appears to be in the Catalina Foothills School District of Tucson, Arizona. In that community the necessary building blocks for successful educational innovation have come together. Progress in that school system rests on:

1) fundamental new concepts of education,

2) a receptive community,

3) talented teachers who are willing to try unfamiliar ideas and who are at ease in the nonauthoritarian environment of learner-centered learning,

4) a school administration that is applying a systems viewpoint in seeking total quality, mutual understanding, and continuous improvement,

5) a supportive school board,

6) and a "citizen champion" who, without a personal vested interest in the outcome except for a desire to facilitate improvement in education, has helped by inspiring teachers, finding funding, arranging for computers,

> and, above all, facilitating convergence of political differences in the community.

The Catalina Foothills district did not have its own high school. Students went into the Greater Tucson system. After seeing the impact on several hundred students of the new educational philosophy embedded in the Orange Grove junior high school, parents became reluctant to have children revert to a traditional high school. The District in 1990 voted a $30 million bond issue to create a high school in the educational pattern that had been pioneered in the junior high school.

In March 1992 a “Systems Thinking in Education Conference” was held in Tucson. Two hundred people attended six plenary sessions and seven sequences of parallel sessions. Enthusiasm was high with reports of systems activity from fourth to twelfth grades.

The Educational Testing Service has established the Systems Thinking and Curriculum Innovation Network Project (STACI) involving about a dozen schools to explore the use of system dynamics in classrooms.[4]

> “The approach consists of three separate but interdependent components: system dynamics, the theoretical perspective; STELLA, a simulation modeling software package; and the Macintosh computer.… The STACI Project is an implementation and research effort that examines the cognitive and curricular impact of using the systems thinking approach in pre-college instruction.… Because it is critical for teachers to be able to seek assistance easily from experts and other teachers, an electronic mail network using AppleLink has been established among the schools… the project focuses on the examination of cognitive and learning outcomes.… the systems approach is being used in courses that reach a range of students. Contrary to initial beliefs, the perspective can be used to facilitate instruction of low- as well as high-ability students.… from initial results, the use of the systems approach for less able learners seems to be yielding promising outcomes.” (Mandinach and Cline, 1989)

Some other countries are moving ahead rapidly in using system dynamics as a foundation for an educational system below the college level. The Scandinavian countries are working together. Davidsen[5] describes their guiding philosophy:

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[4] Ellen B. Mandinach and Hugh F. Cline, Educational Testing Service, Princeton, NJ 08541, USA.

[5] Pål I. Davidsen, Department of Information Science, University of Bergen, Thormøhlensgt 55, N-5006 Bergen, NORWAY.

> "System dynamics is a method, used in the study of complex, dynamic systems. Its pedagogical qualities are under investigation in several countries.… our final goal is to provide our students with an effective way of thinking about complex, dynamic systems. Thus we want to change their cognitive style. Far beyond establishing a basis of values, attitudes, and factual knowledge, our schools significantly influence the way each one of our students will be thinking.… we encourage our students to become critical users of models and to question assumptions underlying models, used for professional and political purposes. They should gain respect for real life complexity and variety and question simple solutions to complex problems.… In Norwegian and Nordic schools, we have chosen to utilize the conceptual framework offered by system dynamics for our educational purposes… When we have established an understanding of the basic dynamic processes, we are ready to address ourselves to reality. Then we will have to tackle systems of far greater complexity, typically characterized by feedback, delays, nonlinearities, and noise.… (pursuing) causal chains until they close upon each other, leads us to a multi-disciplinary approach.… Academic boundaries no longer constitute the boundaries of our imagination or our investigation. Historic and economic considerations are merged with physics and chemistry in our study of ecological issues." (Davidsen, 1990)

I have received a German book detailing their experimental use of system dynamics and the STELLA software for teaching high school physics (Bethge and Schecker, 1992).[6]

Several schools are making good progress with system dynamics and learner-centered learning below the level of junior high school students. In the public schools of Ridgewood, New Jersey, Timothy Lucas and Rich Langheim have been focusing on first through fifth grades.

5. The Future

Over the next several decades, an improved kind of education can evolve. The growing frustrations in corporate, economic, social, political, and international organizations demonstrate the need for better understanding. The basis now exists for a far more effective educational process. But a vast amount of work remains to build on the present foundation. Adequate educational materials are yet to be developed. One book was written especially for high schools (Roberts, et al., 1983) . Although not written specifically for pre-college use, other introductory system dynamics books are available (Forrester, 1961; Forrester, 1968; Forrester, 1969; Forrester, 1975; Goodman, 1974; Richardson and Pugh, 1981). Nevertheless, the published material does not yet adequately convey the background, simulation models, related teacher-support materials, and

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6 Horst Schecker, Institute of Physics Education, Department of Physics, University of Bremen, Postbox 330440, D-2800 Bremen 33, GERMANY.

guidance on teaching methods. Much material already exists in places ranging from files at MIT to work of teachers who are pioneering in systems thinking and learner-centered learning. But most existing materials are not now widely accessible.

No network has existed before 1992 for interchanging information among all interested innovators in pre-college education. But that missing link is now being remedied by a new office, the Creative Learning Exchange,[7] established by John R. Bemis, to receive, print, and distribute system dynamics educational materials. That office will maintain communications among schools, encourage training seminars for teachers, advise teachers in preparing new materials for wider dissemination, and assist in maintaining the integrity and practicality of the system dynamics content of emerging curricula.

A group of students in the MIT Undergraduate Research Opportunities Program are working with me to develop educational materials for use in schools. They are working with teachers in the Cambridge Rindge and Latin High School to test materials and acquire experience in the real world of teachers and classrooms. In a current project they are creating a “Road Maps” agenda for self study in system dynamics as applied to education. The agenda is a guide to using available published material, which will be supplemented by papers written by the students and some selections from more than 4000 memoranda in the files of the MIT System Dynamics Group. The material from this “System Dynamics in Education Project” will be distributed through the Creative Learning Exchange. This project is creating examples of quality systems work to help establish standards for educational programs. It is not the intention to create entire unified courses of study, but rather to generate examples that teachers can use in a wide range of educational settings.

Many private individuals are moving ahead to provide financial assistance to the development of systems education, rather than waiting for public political organizations to innovate. Private support can operate with a freedom and a clarity of purpose that is seldom possible with the bureaucratic processes of government and large foundations.

I believe that the immediate goal is to reach a point where at least twenty schools have been unambiguously successful and have achieved self-sustaining momentum. Thus far, many schools are making good progress but are still

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[7] Ms. Lees Stuntz, Executive Director, Creative Learning Exchange, 1 Keefe Road, Acton, MA 01720, USA, tel: 508-287-0070, fax: 508-287-0080

relying on outside guidance to assist when barriers are encountered. Some are beginning to emerge from such dependence on external assistance, but there are not yet sufficient examples of on-going, independent successes to over-shadow failures that are almost certain to occur. Preliminary results from system dynamics in primary and secondary schools show such promise that too many schools without the ingredients for success may begin, then fail. As a result, systems education might be discredited unless sufficient successes have been demonstrated to sustain the hope and promise of a more effective education.

The politics and processes of moving from a traditional school to a radically different style of education must be better understood. No one yet knows what percentage of present teachers can make the transition from traditional teacher-dominated classrooms to the free-wheeling, research atmosphere of a learner-centered classroom. To some teachers, the transition is threatening. Little is known about how to evaluate students coming out of this different kind of education. Standardized evaluation probably is not desirable or possible in a program that emphasizes individual development and diversity.

Creating a new kind of education will take substantial time. Planning and funding should provide for long-run continuity based on step-by step progress. Funding will be needed for developing materials, retraining teachers, and launching demonstration schools.

A core of system dynamics experts should monitor progress and continually nudge the activities toward higher quality. There are many ways in which erroneous concepts can creep into such an education. If such fallacies go uncorrected, systems education may be perceived as superficial and unsound and lead to negative backlash. Contributions are essential from experienced teachers, who understand the problems and opportunities in class rooms, and can translate ideas into effective teaching materials. “Citizen champions” can serve an important role to draw together teachers, school administrators, school boards, parents, concerned public, and governmental officials. Such influential groups are beginning to coalesce around the combined concepts of system dynamics and learner-centered learning.

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