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This article addresses the widespread belief that today's public schools are not preparing our youth to conquer the problems of tomorrow. Although there is consensus within both academia and business that the need for reform is urgent, there is no generally accepted strategy for achieving improvement, nor is money to finance the job readily available. Creative ideas by great teachers are certainly the nucleus for reform, and contrary to common opinion, there are many good ideas and many great teachers.

But teachers are not the only players. All schools are dynamic systems of great complexity. Unfortunately many essential features of school system structures are poorly understood. As a result, well-intended attempts at reform in the past 50 years have often merely tweaked the system rather than implanting permanent improvement. Most proposals have focused on more math, more science, longer school days, or more homework without understanding why there is such small yield from what already exists in the schools. I believe that only by a major restructuring of the relations between students and teachers, by the adoption of a new paradigm for the teaching-learning process, and by the introduction of modern technology into the classroom will our schools fulfill the demands that the future will make on students.

The restructuring program described in this article has been carried out in the Orange Grove Middle School in the Catalina Foothills School District, Tucson, Arizona.

The Genesis of the problems

As most nations have acquired technology for energy, satellites, radio, television, telephones, automobiles, jet aircraft, bio-materials and better health care—to name only the most obvious—expectations for further increases in material standards of living have expanded. But as these expectations are realized, societies everywhere have begun to perceive a shrinking of resources like water, food, and fuel while experiencing major increases in pollution and more stress and instability in their societies. Our world is now a vast and complex interdependent dynamic system for which the buzz words are "everything affects everything else." All citizens increasingly need to be educated to more than a casual understanding of the complexities and interdependence of events happening around them. And for those who make the big decisions that affect our daily lives—especially business leaders and government officials—it is crucial that such understanding be substantial.

System Dynamics Review 8 (no. 1, Winter 1992): 83-89. ISSN 0883 - 7066. © 1992 by John Wiley & Sons, Ltd.

There has been an avalanche of new technology during the last half century. Prior to that, much of what teenagers learned in high school could serve them throughout a lifetime. But that simple view of education no longer applies. Everyone must know not only more facts but also how the world operates. The mere learning of fragmented information is inadequate. Facts must be anchored to meaning so that knowledge can be used in creative and benign ways. By teaching our youth to be systems thinkers, and by giving them the skills to put knowledge to use, they will stand a far better chance of becoming wise participants in society.

But the traditional paradigms guiding most precollege schools rarely prepare students to be systems thinkers. Education has taught little about dynamic situations—how things change through time. In most high schools the structure of the curriculum is strongly discipline oriented. The peer demands on teachers for recognition, their heavy teaching loads, and the specter of the college-board examination hurdle facing their students, all work against efforts of teachers to establish dialogue with teachers in related disciplines. As a result, too many students acquire, at best, only a fragmented body of knowledge, which often is remembered only until the next quiz.

The integration of unrelated facts into an understanding of how the real world operates is usually left to the students. Too few achieve such an integration. Fortunately, the emphasis on learning by disciplines is less in junior high and middle schools. The disciplinary emphasis is usually insignificant in elementary schools. Because of fewer disciplinary barriers, I believe the place to begin restructuring our public education system is at the elementary and middle school levels.

Even so, the education of present teachers in elementary and middle schools failed to stress the importance of interdisciplinary knowledge. Also the idea of teaching systems thinking was rarely mentioned. Many teachers not only need to change the way they look at their role in the classroom but also to change the way they view the world. This calls for a new paradigm, along with unlearning much that was learned in the past.

Coping with change

A key feature of Jay Forrester's work, familiar to readers of this journal, is his stress on the fact that we daily encounter systems—in the home, in the body, when controlling air traffic, or when managing a business. A great many teachers fail to realize the urgency of letting students know this by bringing systems thinking into their teaching. In all real-life situations, the character of system structure, including cause and effect relations within feedback loops, determines the dynamics of behavior. It is essential to learn these concepts to understand how the real world works. Also, it is important to know that feedback can be either positive or negative, depending on the properties of the system components. Positive feedback creates all growth processes. Negative feedback exerts control and gives stability but can also cause oscillation.

There is no doubt in my mind that there is a big difference between systems thinking and critical thinking as usually interpreted. I have noted that students often have a fuzzy understanding of the words *fact*, *knowledge*, and *wisdom*, which reminds me of the words written in 1795 by William Cowper in his poem "The Task" (Cowper 1908):

Knowledge and wisdom, far from being one,
have oftimes no connexion. Knowledge dwells
in heads replete with thoughts of other men,
wisdom in minds attentive to their own.
Knowledge, a rude unprofitable mass,
the mere materials with which wisdom builds,
till smoothed and squared and fitted to its place
does but encomber whom it seems to enrich.
Knowledge is proud that he has learned so much;
wisdom is humble that he knows no more.

As I reflect on these lines, I conclude that in the first four Cowper is saying that too much of our knowledge (information or mere facts) is fragmented, and in lines 5-8 he is saying that it is through the interconnectedness of knowledge that we achieve understanding. This is a poet's way of saying that structuring ideas and putting them in correct relations are essential to understanding. It is the road to gaining wisdom, in other words, systems thinking.

Draper and Swanson (1990) describe a learner-directed systems education program comprising a new paradigm, new learning procedures, and new educational tools that have been introduced into the 7th and 8th grade general science curriculum at the Orange Grove Middle School in Tucson, Arizona. After one sees what Draper and Swanson have achieved by implementing systems thinking with Macintosh computers and STELLA software to model and simulate systems, it is clear that both the concepts and the tools for problem analysis can be introduced at the middle school level.

The use of computers in the classroom (not in a computer lab) has, for us in Tucson, resulted in a unique learning environment. It is not necessary to teach the Macintosh computer to 7th or 8th grade students. They learn what they need to know as the teacher guides them through a simulation in class. They work in groups of two or three 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. Before doing a simulation, the students spend several class periods gathering information about the topic, take notes during lectures, learn about a library, and read references. Then, working as a group, they plan the simulation. By working this way Draper's students do not merely try to remember the material for a test but actually use it in a project simulating real-life situations. This has led us to identify a new paradigm that we call systems thinking and learner-directed learning.

At the classroom level, a single teacher can fine-tune the subject matter, but because of the difficulties of collaborating with teachers in related disciplines, and the shortage of time and money, the effort will have only a small effect. At the school level,

it is not always clear who is in charge of reform. Is it the teacher, the superintendent, the school district, or the state school board? But regardless of who has the responsibility, a public school is not amenable to change by methods commonly accepted in industry.

Dr. Richmond points out that achieving academic change is like working up a recipe—it is not merely possessing the right ingredients, such as knowledgeable and good teachers, enlightened administrators, and an acceptance of the need for change, but the ingredients must be blended in the right sequence in the right amounts, and baked for the proper amount of time. As in cooking, there is an art to academic administration.

A few other often overlooked ingredients need mention:

- Primary legal responsibility rests with the state and local school boards.
- Many teachers graduate from teacher training colleges with a license to teach only one specific subject.
- Schools comprise hardware such as buildings and equipment, and software such as codes and regulations, and all must be constantly updated to remain compatible.
- There must be an understanding that information should flow both up and down among students, teachers, the administration, the school boards, the parents, and the general public.
- The patrons of public education are the taxpayers, and they must be kept informed.
- The administrator must be a person who, instead of merely tolerating reform-minded teachers, must support them by creating an environment where new ideas can be nourished and integrated into the curriculum.

In addition, Dr. Richmond identifies a source of help not officially a part of the school system: "the citizen champion," whose role is to become involved, daily at times, to open doors, to anticipate needs, to find money, and in many instances, to identify closely with teachers and bring credibility to a program.

Without realizing it, I have been playing this role of citizen champion in the Catalina Foothills School District (CFSD) Middle School. Also, Mrs. Kenneth Hayden, who introduced me to public education in Tucson in the Fall of 1987, has played this role since she began her work with students and teachers to introduce "Dialogues in Action" into the elementary schools. Frankly, the more I think about the problem of achieving restructuring, the more I believe that the citizen champion is essential.

Where we are now

A number of new components to the restructuring effort now exist in our project in Tucson. One is the program that Mrs. Hayden began in the Tucson Unified School District (TUSD) elementary schools two decades ago. To support her program, she formed Ideals Associated, a nonprofit foundation, and funded it privately. During the conduct of her work she learned that it is in the 4th grade that students encounter trouble with writing, reading, speaking, listening, working with others, and developing self-esteem.

Mrs. Hayden's program, emphasizing working in pairs, has salvaged many at-risk students from a dead-end future. To her surprise, the "Dialogues in Action" program hastened the academic growth of both average and gifted students. The at-risk group made the most rapid gains in language, reading, and computation. The act of taking charge of a partner's learning converted impatient and highly competitive high achievers into team players.

The second component to the restructuring is the presence of a remarkable teacher, Frank Draper, as leader. He became involved as a result of my attendance at a neighborhood meeting when the superintendent of our CFSD district was soliciting voter support for a forthcoming bond issue to build a new high school. Here I learned of the superintendent's interest in a high school that would differ in both substance and structure from traditional high schools. I met with him and asked that he consider introducing the subject of system dynamics into the program. I showed him my copy of *An Academic User's Guide to STELLA* (Richmond et al. 1987), and after about 20 minutes he said, "Please go and see Frank Draper." This I did. Frank Draper's and my interests were mutually reinforcing. The learner-directed systems education program emerged and has become visible, viable, and vigorous at the middle school level. On February 27, 1990, the school board approved a new mission statement (Draper 1990) for the curriculum of Frank's school and the new Espero Middle School, which will open next fall. In both schools, an "interdisciplinary approach to curriculum planning and learning", and the "development of systems thinking as a means of viewing the world as an interdependent dynamic system," play central roles. Since its beginning about two years ago, the systems thinking program in the Orange Grove Middle School has been funded by additional private support given to Ideals Associated.

All this leads me to conclude that the optimum level to begin the introduction of systems thinking is at the 4th grade level, then work up through the middle school to high school. Progress in introducing systems thinking is apparently achieved much more quickly and more economically when the effort begins in an elementary or middle school. Elsewhere in the country, however, most effort is focused on high schools, where discipline pressures are strong and where the difficulties of making change are great.

Because high schools are usually located at sites away from elementary schools, there is inherently a time delay before the lower schools hear about advances in teaching in the high schools. But when the change takes place first in the lower school, the students will take with them information about improved teaching practices as they move to the higher grades on other campuses, and thus generate pressure for change. Also, they will be prepared for the more advanced study of systems that a high school should offer.

This is no mere "trickle up" situation. On the contrary, it is a powerful means for extending reform throughout a system. Student flow upward takes information flow upward.

Some of the key features of our program are as follows:

- A new paradigm, namely "systems thinking with learner directed learning."
- The leadership of the program comes from within the school, specifically from Frank Draper, who is a very talented teacher with a great vision of the future. During the past two years he has combined his skill at developing computer software with his broad background in education and industry to develop about 30 models and simulations of real-world problems. He has now been joined by his colleague Mark Swanson. Our principal, Ms. Mary Scheetz, has established teams of 7th and 8th grade teachers to promote interdisciplinary planning and teaching.
- We have adopted a considerable amount of modern technology and use it to achieve enhanced learning and improved efficiencies in operation. Our Macintosh computers were a grant from the Apple Computer Company and we are a member of the Apple Classroom of Tomorrow Program.
- Our administration is skilled at encouraging information flow upward from the troops in the trenches, whereas in many places information (orders) flows only downward.
- Our administration knows that the hardware and the software in a school system must be kept compatible, which means that the environment is constantly monitored and updated.
- We have citizen champions who work at the task and are welcomed by the teachers and the administration.

Frank Draper paraphrases George Bernard Shaw by saying, "We now have students in search of knowledge, not knowledge in search of students."

References

- Ashby, E. 1962. The Administrator: Bottleneck or Pump? *Daedalus* 91 (2).
- Carnegie Council on Adolescent Development. *The Turning Point*. New York: Carnegie Corporation.
- Cowper, W. 1908. Book VI, "The Winter Walk at Noon." In *The Poetical Works of William Cowper*, ed. W. Benham, 267, lines 88-98. London: Macmillan.
- Draper, F. 1990. The World of Systems: A New Elective for 7th and 8th Grade Students at Orange Grove Middle School, Tucson, AZ 85718, U.S.A.
- Draper, F. and M. Swanson. 1990. Learner-Directed Systems Education. *System Dynamics Review* 7 (2): 209-213.
- Forrester, J. W. 1990. System Dynamics as a Foundation for Precollege Education. System Dynamics Group Working Paper D-4133. Sloan School of Management, MIT, Cambridge, MA 02139, U.S.A.
- Richmond, B., S. Peterson, and P. Vescuso. 1987. *An Academic User's Guide to STELLA*. High Performance Systems, Inc., 45 Lyme Rd., Hanover, NH 03755, U.S.A.
- Senge, P. M. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday/Currency.