

# SYSTEM DYNAMICS AS AN ARTIFACT\* FOR THE SYSTEMS AGE

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*\*A tool to promote a new way of thinking or a new view of reality.*

## ABSTRACT

Diverse evidence suggests that western society may be in the midst of evolving fundamental assumptions, beliefs, and perceptions more consistent with a systemic world view. Pulled by this undercurrent, tools like system dynamics can focus the forces of change and bring them to bear more directly on pressing societal problems.

## 1. INTRODUCTION

System dynamics is a general-purpose tool for understanding complex systems and, through application of the tool, is gradually developing into a body of knowledge concerning the nature of such systems, especially complex social systems. The tool is unique in its broad applicability to biological, ecological, family, group, corporate, urban, and larger societal systems.\* It is powerful in its ability to integrate traditional points of view and reveal previously unseen innovative approaches to problems. It is clarifying both as an analytic and educational tool, often providing the basis for broadening public understanding of important social issues, as well as contributing to improved corporate policy. Yet, despite numerous successful applications over the past 25 years, the field has grown slowly. Compared with more well-known fields of similar age like operations research, the number of competent practitioners is small. The awareness of policy-makers of the tool and its possible uses is very limited.

Numerous causes for the relatively slow spread of system dynamics have been hypothesized: excessive focus on research versus education, the consequent shortage of quality teaching materials and teachers, the shortage of tools for more advanced practitioners, and the general difficulty in establishing a field that shares little in common with more established methods in the social and management sciences. This paper suggests that the forces limiting the spread of system dynamics to date may be more fundamental than those that naturally impede any radical new theory or methodology in science. These forces concern the social and cultural milieu within which the tool has been applied.

System dynamics embodies a particular world view. According to this world view, at its deepest level, the substance of reality is interrelationships: how the different constitutive elements of a system affect and in turn are affected by one another. Producers and consumers, customers and competitors, family and self have little *intrinsic significance as objects or quantities in themselves*. What is significant is how these variables *interrelate* to produce evolving patterns of change: growth, saturation, oscillation, decay.

This dynamic, systemic world view is relatively new to Western culture. Decision making, at the personal, corporate, or national level is most frequently guided by a world view that focuses on objects, events, and the separation of the individual decision maker from the people or things he seeks to influence. We discipline a child, teach a student, develop a new product, or enact a new law — with little attention to the complex and often unanticipated ways these isolated actions “feed back” to influence ourselves and our future decisions. We view the world through a lens of separateness. This lens profoundly influences what we see and how we attempt to influence the world around us. And, like any lens which is almost always in place, we are rarely aware of the way it shapes our perceptions.

The mismatch between the basic world views underlying Western culture and system dynamics may be the primary reason why system dynamics has not found more rapid acceptance. But, cultural world views change. The central thesis of this paper is that such a change is currently occurring and that the particular nature of this change is toward a more systemic, holistic world view. Such a change has been predicted in the past and is being documented by many current writers. Understanding this change is of the utmost importance for system dynamics practitioners, both for the future demand for system dynamics *and* for the possible role the field may play in influencing the emerging new world view.

## 2. A QUIET REVOLUTION

For many years keen observers of Western society have been predicting a fundamental transition in world view. Beginning over 50 years ago, Pitirim Sorokin, founder of the sociology department at Harvard University, predicted that materialism would stagnate as individuals lost their desire for increasing material standards of well being. Sorokin argued that Western society was at the end of an approximate 600-year epoch of “sensate culture”, a culture “based upon the ultimate principle that true reality and value are sensory and that beyond . . . [that] which we can hear, smell, touch, and taste there is no other reality and no real values (Sorokin 1964, p. 17).” By contrast, “the culture and society of the Middle Ages were based upon . . . the ultimate principle that the true reality, or value, is supersensory” and that the sensory world is “a mere mirage” (Sorokin, p. 17, 18). In an

\*A thorough survey of past system dynamics studies is beyond the present scope. Roberts (1981) provides a survey of corporate applications. The work of Forrester is well known in urban (Forrester 1969), global (Forrester 1971 and Meadows et al. 1972), and national (Forrester 1976, 1977, Graham and Senge, 1980) modeling. Other areas of significant application include energy and natural resources (Naill 1977, Sterman 1981), education, health systems, and human physiology.

"ideational culture" such as that of the Middle Ages, theology is the queen of sciences, since society "concentrates its cognitive energy on study of the Kingdom of God and on a realization of values during man's short earthly pilgrimage to eternity" (Sorokin, p. 18). With the end of the Middle Ages eventually came radical shifts in art, science, government, and economics. Art became more "realistic", bringing both style and subject into greater agreement with sensory reality. Modern science and technology began to develop based upon experimental study of the physical world. Governments gradually became less theocratic, and spiritual authority over secular affairs waned, paving the way for more populist governance. The rule of religious and moral commandments in economics similarly weakened, leaving only the laws of the marketplace.

The dominance of sensate culture began to weaken with the discoveries of 20th-century physics that sensory data were inadequate for understanding the physical world. The table that *appears* to us solid is in fact mostly empty space at the subatomic level. Our whole perception of matter is, in a very real sense, an illusion of our senses. Sorokin saw the discoveries of 20th-century science as just one facet of the breakdown in sensate culture. He argued that the personal emphasis on "external reality" would ultimately prove inadequate as the primary needs for material well-being were satisfied leaving a significant segment of society searching for deeper levels of fulfillment.

Sorokin predicted that the decay of sensate culture *might* eventually give way to an "integrated culture" that balanced and even integrated the spiritual and material emphases of the prior epochs —

"[that paid] attention to the empirical as well as superempirical aspects of the true reality-value. Science as well as philosophy and theology blossom (in such a culture). . . and they harmoniously cooperate with one another" (Sorokin, p. 22).

According to Sorokin, emergence of an integral culture is characterized by 1) increasing concern with the moral and ethical consequences of science, 2) increasing emphasis in education on the balanced development of creative as well as intellectual abilities, and 3) increasing acceptance of "superrational-supersensory intuition" as the vital complement to rational analysis in effective problem solving.

Although many of Sorokin's predictions (as well as similar predictions by de Chardin and Lewis Mumford) may still seem futuristic, there is ample evidence that many of the fundamental cultural changes he foresaw have occurred. For example, Yankelovich argues that profound shifts in basic cultural values and attitudes are evident in public opinion surveys over the past 20 years (Yankelovich 1981). He documents a fundamental, grass-roots shift away from many basic values that previously characterized American culture. He sees a more "sacred" world view emerging:

I use the term sacred here in opposition . . . to the merely instrumental. The distinction is important. We adopt an instrumental philosophy whenever we ask about something: what is it good for? From that perspective a tree is good for lumber, or for giving shade, or for enhancing the appearance of the landscape. A forest no one harvests or sees

is not good for anything . . . People and objects are sacred in the sociological sense when they are valued for themselves, apart from their instrumental use [Yankelovich 1981, p. 85].

Yankelovich points out that instrumentalism as a personal outlook is essential to a materialistic society. He believes that survey results clearly show that it is waning, paving the way for "a new social ethic":

There are now scraps and shreds of evidence that American culture is evolving a new ethic of commitment. The word "commitment" shifts the axis away from the self . . . toward *connectedness* [underlining mine] with the world. In the interviews conducted, people often express a longing for connectedness [Yankelovich 1981, p. 85].

An emerging new world view has become a common theme in several recent popular books. For example, Ferguson's *Aquarian Conspiracy* points to modern physics, brain research, systems theory, biology, and chemistry as sources of new views of reality:

Our discoveries about the startling nature of reality are a major force for change, undermining common sense ideas and old institutional philosophies . . . [This knowledge] reveals a rich, creative, dynamic, interconnected reality . . . [Ferguson 1980, p. 145].

Ferguson argues that a primary impact of modern science will be on society's shared assumptions concerning the nature of man and the systems he is part of:

If we believe the universe and ourselves to be mechanical, we live mechanically . . . If we imagine that we are isolated beings, . . . we will lead different lives than if we know a universe of unbroken wholeness [Ferguson 1980, p. 146].

Similar themes echo in the writings of futurist Willis Harman (1979), and physicist Fritjof Capra. Capra is the author of the widely read book *The Tao of Physics*, which traces parallels between the view of reality that has emerged in modern physics and views intrinsic to ancient Eastern cultures. He argues that only in the 20th century has modern science begun to return to the dynamic holistic view that has long characterized many ancient cultures. He asserts that a similar shift is gradually occurring in other branches of science:

A massive shift in the perception of reality is underway, with thinkers in many disciplines beginning to move away from the traditional reductionistic, mechanical world view to an ecological, holistic systems paradigm . . . (Capra 1982b, p. 19).

Such shifts in prevailing assumptions about the nature of reality do not occur smoothly:

The relativistic view of reality was by no means easy to accept for the physicist in the early 20th century. The exploration of the atomic and subatomic world brought them in contact with a strange and unexpected reality. In their attempt to grasp this reality the scientists became painfully aware that their basic concepts and their language, and their whole way of thinking, was inadequate

to describe the atomic phenomenon. The problem was not merely intellectual but amounted to an intense emotional, and one could even say existential, crisis. (Capra 1982c, p.29).

The view of reality that eventually began to emerge replaced the Newtonian view of a "mechanical system composed of separate objects with "holistic" reality composed of a "complex web of relationships":

Sub-atomic particles cannot be understood as isolated, separate entities, but have to be seen as inter-connections . . . The notion of separate object is an idealization that is often very useful but has no *fundamental validity* (Capra 1982b, p. 21, emphasis mine).

Capra argues that this systemic view has been resisted in the social sciences where research is still governed by the reductionistic, "mechanical" views of Newtonian physics:

Present day economics, for example, fails to recognize that the economy is merely one aspect of the whole ecological and social fabric. Economists tend to dissociate the economy from the fabric and to describe it in terms of highly unrealistic theoretical models . . . whereas the surrounding ecosystems are self-balancing and self-adjusting organic wholes, our current economies and technologies recognize no self-limiting principle (Capra 1982b, p. 20).

He suggests that the understanding of physical reality in modern physics is most likely to be translated into the social sciences through general systems theory:

The systems view looks at the world in terms of relationships and integrations. Systems are integrated wholes with unique properties of their own that cannot be reduced to or understood by simply combining the properties of smaller units. Instead of concentrating on basic building blocks or basic substances, the systems approach emphasizes basic principles of organization (Capra 1982b, p. 22).

### 3. EVIDENCE IN THE WORKPLACE

Writers like Ferguson and Capra support their thesis primarily through analysis and speculation focused on developments in modern science, coupled with observations on the breakdown of traditional nonsystemic ways of dealing with key social problems. Another important source of evidence for an emerging systemic world view lies in new ways of managing large organizations. Moreover, because it deals with the attitudes and perceptions of policymakers, the new management style is especially relevant for system dynamics.

In recent years, managerial and organizational innovation has begun to attract increasing attention. The wide spread interest in Japanese management techniques appears to be a symptom of a much deeper re-examination of fundamental assumptions in management. A small number of corporations are emerging as pioneers in a new, more systemic approach to organizational design and management. These organizations are loci for operationalizing the underlying shift in systemic awareness. Moreover, they are showing how the shift to more systemic modes of operation can influence individuals throughout

a system. That is, they are developing a set of attitudes and beliefs along with a set of design principles and management methods.

One common element to these new organizations is a sharp break with the hierarchical philosophy underlying traditional organizations. The organizations strive for an environment in which each and every individual shares a sense of responsibility and ownership for the system as the whole. As Ray Stata, president of Analog Devices, and founder of the Massachusetts High-Technology Council, observes.

"Much of our traditional organizational thinking is derived from the Catholic Church and the Roman Army — institutions predicated on the notion that the person at the top has information and influence not shared by others". (Kiefer and Senge 1982, p. 116-117).

The first step of an organization towards a more systemic orientation is to pierce the illusion of the hierarchy that suggests that only a small number of people are responsible for the performance of the system as a whole, while the great majority are mere "cogs in the wheel". This does not imply the elimination of all authority, but most fundamentally the creation of a new value system. As Stata says,

We're not trying to eliminate all hierarchy at Analog, but to undercut the value system that is linked to the hierarchy. The greatest limitation in traditional organizations is that people further down the hierarchy somehow consider themselves as lesser beings than those above them. (Kiefer and Senge 1982, p. 114).

Many corporations are evolving radically decentralized organizational designs to sustain this new value system. One example is the Kollmorgen Corporation, a diversified manufacturing company where divisions continually divide as they grow. People at Kollmorgen believe that whenever an operating division becomes too large, it becomes impossible for each individual to understand the system as a whole and feel responsible for it. Divisions rarely exceed 400 or 500 people. As new business opportunities develop, small sub-divisional groups initially form. If these "product teams" succeed and grow, they eventually split off from their divisional parent and become a new free-standing business unit. A similar approach is followed at W.L. Gore and Associates, manufacturers of synthetic fibres and related products. At Gore, working units are generally kept to 200 or less.

Corporate control in companies like Kollmorgen and W.L. Gore is kept to a bare minimum. For example, in a corporation of approximately 5,000 employees, the corporate staff at Kollmorgen numbers around 25, including secretaries and accountants. Divisions are run as virtual free standing businesses with complete profit and loss responsibility and their own divisional board of directors. Virtually all operational control is at the divisional and sub-division level. Corporate strategic and financial responsibilities are carried out through a "Partner's Group". The Partner's are all Division presidents and corporate officers. The group operates by consensus. Each partner has a veto on all basic corporate decisions.

Managers in such companies develop new views of management control. Unlike the "top-down" approach assumed necessary for most of our major social issues, these organi-

zations believe strongly in the effectiveness of local initiatives to deal with complex problems in the organization. Stata emphasizes "organismic control" — local control for local problems. At Gore, the need for local solutions to local problems is reinforced by the complete absence of formal hierarchy: there are no titles, and no bosses among some 3000 employees. As founder Bill Gore puts it, "We don't manage people here. We organize around voluntary commitments — there's a fundamental difference between a commitment and a command".

The strong emphasis on personal responsibility in these companies means a great deal of freedom and open flow of information within the organization. People at the local level cannot be expected to be effective problem solvers if they do not have good understanding of problems and key interrelationships within the organization. Bob Swiggett, president of Kollmorgen, stresses the importance that everyone within the organization share access to all basic information regarding organizational performance and how the organization operates. Only within an environment with open information can individuals act responsibly. Senior managers like Swiggett must work continually to undermine information monopolies, whereby managers traditionally have attempted to solidify political power within organizations.

Swiggett, Stata and Gore are illustrative of the new role for senior managers in the evolving decentralized organization. Whereas chief executives in traditional organizations are, above all else, decision makers, chief executives in the emerging organizations are, above all else, teachers and designers. They participate in decision making, but their success is predicated on their ability to create an environment where quality decisions can be made by others.

Moreover, their management philosophy gives them time and opportunity for important activities that traditional managers typically neglect. They have the time to think about how the organization functions as a system, how it interacts with its environment, and how it is evolving. They have the time to teach others how the organization functions, the values that are critical to its integrity, and the philosophy that guides its development. In my experience, senior managers in companies like Kollmorgen may spend 50% to 75% of their time in key strategic and educational activities. By contrast, more traditional control-oriented managers are able to allocate only a fraction of this time to these critical activities.

It is impossible at this time to accurately assess how widespread such corporate innovation is. It appears to be quite widespread within the 'high-tech industries', where sustaining creativity and innovation is critical. However, current research indicates that many of these ideas are taking hold in industries as diverse as retailing, consumer goods, and traditional manufacturing. Much research needs to be done to better understand this new organizational thinking and practice and to assess its relevance for the public as well as the private sector.

#### 4. THE POSSIBLE ROLE OF SYSTEM DYNAMICS

The possible impact of system dynamics in the transition to a systems age needs to be examined in the broader context of the generic interaction of technology and culture. This problem is an important research area for cultural anthro-

pologists, where many case studies have shown how accelerated transitions to new cultural configurations can occur when tools commensurate with the new culture are introduced. Inventor, philosopher, and futurist Buckminster Fuller argues that appropriate tools can be of the utmost importance in precipitating immanent cultural shifts. Much of Fuller's work involved developing appropriate "artifacts" to speed the transition to new ways of thinking. Such tools allow people to go beyond talking about a new way of approaching problems—they allow people to act differently (see Fuller 1981).

One can begin to understand the importance of artifacts on cognitive development effects of the first tools on human evolution. At this stage of evolution man was undoubtedly the product of his environment with little cognitive realization of his potential to influence that environment. As he developed facility with his earliest tools, his cognitive world began to change in parallel. Eventually he came to see himself as influencing his environment as well as reacting to it. It is impossible to imagine this shift in attitude and perceptions having occurred independent of practical experience. In this sense, the first crude tools were artifacts for a way of life that would put man on a pathway to the modern world.

What is needed today are similar artifacts to facilitate the transition to more systemic ways of thinking and operating. System dynamics seems a logical candidate. Firstly, it has perhaps unique capabilities to be applied to our most important organizational and societal issues. Unlike many other methods within the field of general systems theory, system dynamics is strongly problem oriented. It has already demonstrated utility in clarifying causes of long term corporate, urban, regional, and global issues. Of course, the methodology is not without its shortcomings, as one should expect for a field at a very early stage of development. However, few other methods can lay claim to having created as much interest amongst analysts and policy makers into the possibilities of social system modeling.

A second great strength of system dynamics lies in its educational possibilities. Unlike many systems analysis tools which remain the province of specially trained experts, system dynamics models have repeatedly been used to teach the public at large about systemic issues. One suspects that this potential strength of system dynamics has been barely tapped, since most studies still today are done for specific clients and not public education. But, it is clear that fundamental policy changes can only take place through education. This is equally true in the nation as a whole and within the corporation. Applications of system dynamics which fail to result in broad education generally fail to have enduring impact.

Because of its applicability to key problems and its strength as an educational tool I believe that system dynamics can play an important role as a bridge between old and new ways of thinking. The "systems age" remains a distant abstraction until one begins to see that only through a systemic viewpoint can we begin to understand social issues such as economic stagnation, inflation, and the nuclear arms race. Public awareness is developing that these are not isolated separate problems created solely through political errors and unfortunate circumstances. Awareness is developing that in some ways these problems are evidence of a basic mismatch between reality

and our normal ways of thinking about and attempting to influence reality. If this emerging awareness can be crystallized and focused through tools like the System Dynamics National Model (Forrester 1976, 1978), system dynamics can play an important role in the coming cultural transition.

## 5. IMPLICATIONS FOR SYSTEM DYNAMICS PRACTICE

The thesis of a societal transition to more systemic ways of thinking provides a challenging context for analyzing the future of system dynamics. It has important implications for:

- 1) How we think about system dynamics
- 2) How we think about ourselves as system dynamics practitioners
- 3) How we apply system dynamics in corporate and public-sector settings

If system dynamics is to realize its potential in the coming systems age, practitioners must learn to view the methodology on two levels: (1) a tool for solving specific problems and (2) a means for developing a more systemic point of view regarding problems. The two objectives are intertwined and may, in fact, be difficult to attain separately.

Fundamental problems in a corporation or larger social system are generally interconnected and difficult to solve in a piecemeal fashion. Frequently, system dynamics applications fail to permanently resolve fundamental problems when the tool is narrowly applied as a problem solving device. The benefits of even highly successful applications often prove only temporary, as policymakers drift back into old ways of thinking and operating. (See, for example, Roberts 1981 or Lyneis *et al.* 1977).

Analogously, practitioners of system dynamics must learn to think of themselves as educators and cultural change-agents rather than as model-builders or analysts. While effective consultants often think of themselves in these terms, system dynamacists rarely appreciate the depth and scope of the educational process which must occur for system dynamics to be truly effective. To be effective in this domain, one must recognize that one's own attitudes and perceptions are often the greatest barrier to overcome. Practitioners of system dynamics are themselves part of a cultural milieu which emphasizes separateness not connectedness. We are like caterpillars attempting to describe to other caterpillars the nature of being a butterfly. We must continually reflect on our own biases and non-systemic perceptions of reality.

This can become very personal. For example, it may very well be that the unquestioned assumption that individuals are essentially separate entities may eventually be seen as a working construct no more "fundamentally valid" than the assumption that atoms are separate objects. We tend to draw an arbitrary boundary around our "self" configured in time and space. This boundary closes us off from our deeper connectedness to the world, manifesting in our personal feelings of isolation and separatedness. As professionals intent on helping others understand the connectedness of the world, system dynamacists more than other social scientists should heed to the challenge of Einstein:

[the human being] experiences himself, his thoughts and feelings as something separated from the rest — a kind of optical delusion of

his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to affection for a few persons nearest to us. Our task must be to free ourselves from this prison by widening our circle of compassion to embrace all living creatures and the whole nature in its beauty.

In addition to the needs for reflection and clearer self definition, the research agenda for system dynamics can benefit from viewing system dynamics as an artifact for systemic thinking. In public sector applications, this will have important implications for who is defined as the audience and how the implementation process is viewed. In many instances, public sector applications of system dynamics should focus on educating the public at large regarding important system problems. All too often, model builders adopt a narrow focus in the misguided belief that answering the "client's questions" is the most sure-fire path to successful implementation of modeling insights.

In a special lecture to an international gathering of global model builders, Jay Forrester painted a different picture of successful implementation and the role of the model builder.

How does the modeler see himself? What audience does the modeler address? . . .

I disagree (with common assumptions). . . that "policy makers" constitute the audience for global modeling.

(Modelers assume). . . that the world is run by policy-makers, apparently referring to people in government. For the great issues now being considered in world modeling, the present people in government are of little consequence. They do not have the power to reverse long-standing tradition. They will not be in office long enough to deal with the issues raised by world modeling.

. . . the audience for the work must be the public in general. In today's social structures, only in the role of the individual as a private citizen does a person take a long-range view of the future. (Forrester 1981, pp. 22, 23).

To put such a view of the modeler's role into practice takes courage, perseverance, and a long-term time perspective — the very characteristics that system dynamicists repeatedly ask to policymakers. Modelers will be more effective in this role as change agents if they recognize that a sympathetic ear for their message is emerging and learn to speak to that ear.

For corporate applications there are also important implications. If system dynamics is to be used as an artifact for systems thinking, the whole consulting paradigm characteristic of most corporate applications needs to be re-examined. Consulting projects rarely result in a lasting shift in the way managers think. Although implementation is almost always the objective, "the implementation stage seldom occurs," in the words of Roberts (1981). Although one or two managers close to the consulting team may develop a new way of looking at a specific problem, such a shift rarely extends to other problems, and I know no case where it has occurred pervasively within an organization.

To be more effective change agents, it will probably be necessary for the system dynamicist to become closer to the organization in many ways. The few consultants I know who seem to have deep and lasting impacts in organizations work with only a small number of organizations and work with those organizations over an extended period of time. In effect, they live within the organization. They become trusted. They become "part of the team". From this role, they can fill a much broader educational function. They can design ongoing educational programs that allow for accumulation and dissemination of systemic understanding. In some cases, effective consultants even sign multi-year contracts with clients as a way of guaranteeing long-term in-depth interaction. Roberts says it is necessary to stay with the process "until implementation is achieved", but that may be much too short a time frame if implementation merely means initially putting into practice a particular set of recommendations.

It may be most effective for system dynamics to be applied to several corporate problems simultaneously. This would greatly increase the likelihood of a shift in the way of thinking within the organization. When one is focused solely on an individual problem, pressures to "solve the problem" force managers to digest the recommendations of the modeler without altering their own understanding. The transferability of insight and approach to other problems is rarely apparent. Ways in which the underlying philosophy and style of the organization give rise to different problems are not seen. The combination of broader focus and extended duration of involvement might go far in enabling modelers to play a more powerful educational role in organization development.

Top management involvement is suggested by Roberts and many other reviewers of past system dynamics applications as important for implementation. But, top management involvement is insufficient for the purpose of organizational re-education unless the top managers see this as part of their

role. This is one reason why applying system dynamics within organizations developing the new management style described earlier may be important. The senior management's focus on education and policy design make such organizations uniquely fertile soil for system dynamics. System dynamics professionals rarely look for such organizations. Nonetheless, we might benefit from reorienting ourselves to organizations with management philosophies more deeply attuned to the system dynamics approach. A great deal of time has been wasted in companies ill-suited for the tool.

Elements of an appropriate management philosophy are

- 1) emphasis on the long term,
- 2) decentralized decision making which requires shared understanding rather than formal procedures for effective co-ordination
- 3) an educational orientation on the part of senior management, and
- 4) an organic (i.e., evolutionary) view of change

The research task of identifying and working with these companies is at a very early stage. System dynamics theorists of organizational change may be able to play a central role in the needed research, both beneficiaries and contributors in understanding the principles and methods underlying these companies.

Lastly, it is of critical importance that the development of educational materials in system dynamics and related systems thinking skills continue as rapidly as possible. Surely, there can be no hope for a broad emergence of systemic thinking until tools for such thinking are a central component of public education. In recent years, great strides had been made in this area (see, for example, Roberts *et al* 1982). However, much remains to be done, especially in the area of training public school teachers how to integrate concepts of systems thinking into their classrooms.

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