Bringing Systems Thinking To A General Audience

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ABSTRACT

The long term success of System Dynamics is largely dependent upon the dissemination of systems thinking to a considerable segment of the general public. A strategy for exposing a non-academic, adult audience to the basic characteristics of systems is developed, using the ADAPT Learning Cycle, System Dynamics, and the Social Fabric Matrix.

INTRODUCTION

> I know that the great tragedies of history often fascinate men with approaching horror. Paralyzed, they cannot make up their minds to do anything but wait. So they wait and one day Gorgon devours them. But I should like to convince you that the spell can be broken, and that there is only an illusion of impotence, that strength of heart, intelligence and courage are enough to stop fate and sometimes reverse it. One has merely to will this, not blindly, but with a firm and reasoned will.
>
> Albert Camus

Our track record to date in solving complex policy problems could easily explain the paralysis exhibited by so many decision-makers at all levels. Aware of the policy failures of the past, constantly confronted by new problems which invariably arise as unanticipated consequences of earlier actions, armed with limited information and inappropriate methodologies, decision-makers are understandably hesitant to embark upon bold new ventures. Furthermore, the most important policy problems are inherently complex, involving multiple stakeholders holding conflicting values, so alternatives and outcomes are impossible to order transitively.

Under these circumstances, the traditional analytic approach, which decomposes problems into separate elements which are regarded as independent entities, is inappropriate. Complex problems require a holistic approach in deriving policy prescriptions. Unfortunately, this is easy to say, but difficult to accomplish.

Recent developments in the various systems methodologies now provide an alternative to the traditional analytic approach. At the same time, a variety of recent policy actions - the PIK program, increased funding for drug enforcement activities, military aid for the Contras - indicates that a systems viewpoint has not penetrated into many major policy decisions. Policy actions are still targeted at particular symptoms rather than at modifying the structure of the system which generated the problem.

From the above, it seems that a relevant task for systems scientists is the development and refinement of methodological tools which will enable decision-makers to routinely use systems thinking in developing policy prescriptions. However, decision-makers should not be seen as the only audience for these tools and techniques. For, as Forrester noted:

> (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. 22-3).

The scientist must be an educator, distilling the general principles of system thinking into a manageable package, whose salient points can be readily transmitted to a non-academic audience. The time constraints facing this audience, as well as the level of intellectual investment required to use a systems approach have to be considered. System dynamics can be an important tool in this educational process, and at the same time can also benefit from the use of other techniques which expose a wider audience to the benefits of adopting a systems perspective.

This paper will briefly outline some basic notions about effective education for adults, discuss the contributions which system dynamics can make to the immediate education of this audience, and will introduce the Social Fabric Matrix as a complimentary vehicle for bringing systems thinking to a general audience.

ANDRAGOGY - THE EDUCATION OF ADULTS

The institutionalized process of education in the Western world is based upon the monastic schools of the Middle Ages. The teaching monks transmitted the reading and writing skills necessary to use and transcribe the sacred books, as well as molding the personal development of the novices so they would become obedient, effective servants of the church. From this monk-novice arrangement, the tradition of pedagogy - literally, the art of teaching children - spread to the secular schools of Europe, and hence to the Americas.

Recently, educators have begun to realize that the assumptions which hold for the teaching of children may not be applicable to the teaching of adults. Thus, andragogy - the art of teaching adults - is receiving increasing attention. The literature does not suggest that there is any fundamental difference in the way that children and adults "learn" - or internalize new information (Ingalls, 1973). Instead, the focus is upon the differences which emerge in the learning process as an individual matures.

The foremost proponent of a separate approach for andragogy, Malcom Knowles, has identified four basic concepts which illuminate the differences between teaching children and teaching adults.

First, a person necessarily goes through changes in self-concept as he matures, moving from the total dependency of an infant to the increasing self-directedness of an adult. Traditional teaching, in which the teacher makes the decisions about material, pace, class structure, and testing procedures violates the autonomy of an adult. When adults discover that they are being treated like children, they allow the teacher to take responsibility for their learning, and as passive participants, learn relatively little.

Second, an adult has accumulated a variety of experiences which represent an important learning resource. The adult is thus able to relate new information to previous experiences, seeing the value of the new information to his own particular situation. The use of lectures, set presentations, and rigid assignments ignores the value of these experiences. Discussion, laboratory work, simulation, field experience and other action-learning techniques are more appropriate in adult learning.

Third, the adult's readiness to learn is not a product of his biological development or academic pressure. Instead, it is a function of the tasks required in the performance of his role as a worker, manager, parent, group leader - whatever his various roles might be.

Fourth, for the adult, the orientation to learning is problem-centered, and his time perspective is immediate. The adult wants to learn something which is helpful in solving a problem which has been encountered. He wants to apply the new knowledge immediately. (Knowles, 1973, pp. 45-90).

Recognizing these characteristics of adult learners, what type of teaching strategy should be employed in bringing the basic concepts of systems thinking to a non-academic adult audience? A standard class-room lecture is clearly inappropriate. So is a typical consultant's presentation, even with its sharp graphics and polished delivery. In both of these situations, the audience is passive.

A manageable active-learning strategy for general audiences can be constructed using three complimentary notions: the Learning Cycle, the Social Fabric Matrix, and System Dynamics. In the following sections, these ideas will be explained, and will be integrated into an active learning strategy.

THE ADAPT LEARNING CYCLE

At the University of Nebraska-Lincoln, a special program has been devised to assist freshmen in their cognitive development. The ADAPT project is a multidisciplinary program aimed at improving students ability to perceive patterns, then to conceptualize from these recognized patterns. To accomplish this task, faculty members have devised a basic strategy known as the ADAPT Learning Cycle, a Piagetian-based educational approach. The program is based upon the Piagetian notion that the development of cognition and thought is an evolutionary process. For each individual, this process moves from the ability to use symbols to represent events, to the ability to classify diverse objects, to the ability to conceptualize beyond directly representable realities. (Piaget, 1970, pp. 30-3).

An ADAPT Learning Cycle is composed of three phases - Exploration, Invention, and Application.

In the Exploration phase, participants are asked to recall, and share past concrete experiences. The instructor supplies encouragement, asks open-ended questions, and suggests alternatives. For example, to underscore the importance of the systems approach, the instructor could ask the group for examples of policy actions which created unanticipated consequences - anti-poverty programs which have created a permanent poverty class, short-term business actions which hurt long-run firm viability, the introduction of new technology which has created whole new sets of problems. (Would puritanical Henry Ford have introduced the Model A if he had known how automobiles would affect teenagers' sex habits?)

The real world experiences offered by the group become the basis for generalizing about the foundational concepts of systems thinking. This process of generalization is the Invention phase of the ADAPT Learning Cycle. Giving hints, and asking questions, the instructor guides the group in the identification of the general characteristics of the systems which had been discussed. From previous work done through system dynamics modeling, a number of significant system characteristics have been identified. While it is unlikely that any group would arrive at these same generalizations on their own, the instructor can guide the discussion to the following general statements about systems, as identified by Forrester:

1. Counterintuitive behavior - intuition and judgment may work in understanding simple systems, where cause and effect are closely related, but intuitive solutions to problems of complex systems are wrong most of the time.
2. Insensitivity to changes in system parameters - large changes in the constants in a system have little influence because of compensating system behavior.
3. Resistance to policy changes - stems from the first two characteristics.
4. Influential pressure points occurring in unexpected places - the system is sensitive to changes in some parameters, but their location is not immediately evident. Hence, policy changes may result in pressures unexpectedly radiating throughout the system from obscure points.
5. Corrective programs counteracted by the system's behavior - internal system dynamics can overwhelm a policy which does not modify the structure of the system.
6. Reactions to policy changes are different in the long-run than in the short-run - short-term solutions are apt to lead to long-run deterioration.
7. Drift to low performance - counterintuitive behavior and short-term expediency lead to detrimental policy actions. If a short-run solution has some positive effect, more of the same is applied, which is detrimental in the long run.

(From DeGreene, 1973, pp. 65-6).

After completing the Exploration and Invention stages, the group has an introductory understanding of some of the problems presented by the complexity of a typical system. The Application phase allows the group to apply this new knowledge in addressing some problem from a systems perspective. If the group has sufficient time and resources, a system dynamics modeling simulation could be undertaken. However, for the general audiences which are the focus of this paper, it is unlikely that the participants would invest the time and energy required for such a project.

Given these constraints, system dynamics may not be a particularly effective tool in the introduction of applied systems thinking for a general audience. For, while system dynamics is a useful tool in understanding complexity, it is also characteristically complex. Even for a simple system, the flow chart and

DYNAMO equations will overpower the uninitiated. It would be difficult to pursue the active-learning strategy which is appropriate for adults without a substantial commitment of time and energy.

Weil's actual experiences in the practical application of system dynamics modeling for various clients is illustrative here. In the first project undertaken, there was little client involvement. Few of the policy recommendations were implemented. Ten years later, client involvement was stressed, with more satisfying results (Weil, 1980, pp. 271-90).

Unfortunately, the level of commitment in time and money required for the intensive client involvement drastically reduces the number of those who are able to participate in the process. Therefore, in introducing systems thinking to the widest possible audience methods other than system dynamics may be more appropriate. One possible alternative would be the construction of a Social Fabric Matrix, which is explained in the following section.

THE SOCIAL FABRIC MATRIX

The Social Fabric Matrix, first introduced by Greg Hayden, is drawn from the institutionalist paradigm in economics. (Hayden, 1982, pp. 637-662). The institutionalists are an amorphous group of non-orthodox economists who draw upon the works of Veblen, Commons, and Dewey for their world-view. While it is dangerous to generalize about any diverse group, typically the institutionalists are characterized as being analytically pragmatic, focusing upon the evolutionary nature of the economy rather than upon traditional equilibrium analysis. The economy is seen as a social institution, constantly changing as new technologies, defined in the broadest sense of all skills, knowledge, and tools, continually alter relationships and offer new possibilities.

As part of their effort to broaden the scope of economic science, institutionalists have argued that it is necessary to view the economy with a holistic perspective. Borrowing the term "holism" from Jan Christian Smuts, whose book on the subject was published in 1926, the institutionalists built a world-view which emphasized the dynamic interrelatedness of both biological and physical systems.

The idea of holism was so central that Allan Gruchy argued that the entire school would best be described as "Holistic Economics" since that term "called attention to what is most characteristic in the new economics: Its interest in studying the economic system as an evolving, unified whole or synthesis, in the light of which the system's parts take on their full meaning." (Gruchy, 1948, p.vii). While Gruchy's suggested appellation did not supplant "Institutionalism" as the generic term for the entire school, the importance of holism to the school has not diminished over time. Thus, in a recent article, Petr includes the holistic approach as one of the ten fundamental institutionalist ideas. (Petr, 1984, pp.1-17).

The adoption of holism as a fundamental concept brought a considerable set of problems to the early Institutionalists however, since they had no methodological tools which were adequate to deal with the complexity inherent in such an approach. Thus, institutionalists have shown considerable interest in the various systems methodologies which are now being developed.

The Social Fabric Matrix is an attempt to integrate a relatively simple system technique - an impact matrix - with the foundational notions of the institutionalist paradigm. According to this paradigm, situations arise out of the complex interactions of social institutions, technology, and the environment. Underlying these interactions are a relatively stable set of basic cultural values, supported by a multitude of norms. Continuing change and conflict, not movement toward an equilibrium, are the anticipated outcomes at all times.

The problem facing the institutionalist researcher was the same problem facing those who are uninitiated in systems education - how to deal with the complexity of the situation being considered.. The matrix allows the system to be broken into a manageable level of complexity, without losing sight of the inter-connectedness of the various components. An example, using the matrix to explore Nebraska's energy system will prove illuminating.

The basic institutionalist notions, arrayed in a matrix, appear as Figure 1.

Figure 1 - Foundational Relationships

Receiving Components / Delivering Components	Institutions	Technology	Environment	Values	
Institutions					
Technology					
Environment					
Values					

The identification of more specific components depend upon the situation of interest to the group. What institutions are important to this issue? What technological conditions? Which environmental factors are important? What values are relevant? An adult group, through its real-world experience, can decide these questions without having any specialized systems knowledge. Different groups may choose different components, just as different system modelers may choose different variables. One example of a matrix for the Nebraska energy system is shown in Figure 2.

The process of specification could continue if necessary. For example, consumers could be separated into residential, commercial, industrial, transportation, agricultural, governmental, and electric utility sectors. Water could be fresh, saline, flowing, falling, underground, polluted, or impounded. As an active-learning event, the group will decide upon the appropriate level of specificity.

There may well be controversy about the inclusion, or exclusion, of particular elements. The instructor should encourage such situations, for the discussion which follows will clarify the role of each element in the matrix. Controversy can also be related to the problems of complexity, which can

Figure 2 - Second Level Relationships*

Delivering Components \ Receiving Components		Institutions			Technology		Environment				
		Governments	Consumers	Suppliers	Existing	Developing	Climate	Water	Land	Flora	Fauna
Inst.	Governments	1	2	3	4		5				
	Consumers	6	7	8	9		10				
	Suppliers	11	12	13	14		15				
Tech.	Existing	16	17	18	19		20				
	Developing										
Environment	Climate	21	22	23	24		25				
	Water										
	Land										
	Flora										
	Fauna										

Notes:

* Values components omitted due to space considerations

1 - Different levelsof government deliver problems, legal controls, and incentives to other levels of government.
2 - Governments deliver income, legal controls, and incentives.
3 - Governments deliver payments, legal controls, and incentives.
4 - Governments deliver controls on the development and use of technology.
5 - Governments protect, or fail to protect, the environment.
6 - Consumers deliver complaints, legitimacy, and challenges.
7 - Consumers have consumption patterns which affect other consumers.
8 - Consumers deliver payments and service needs.
9 - Consumers deliver a demand pattern for different technologies.
10 - Consumers require environmental resources.
11 - Suppliers deliver complaints, legitimacy, and court challenges.
12 - Suppliers deliver energy and other services.
13 - Suppliers deliver energy, payments, and competition to other suppliers.
14 - Suppliers deliver a demand for different technologies.
15 - Suppliers deliver demand for environmental resources.
16 - Technology delivers problems to governments.
17 - Technology delivers efficiency relationships, and unexpected problems.
18 - Technology delivers efficiency relationships, and unexpected problems.
19 - Technology delivers the basis for new technologies.
20 - Technology delivers pollution.
21 - Environment delivers complex problems to the government.
22 - Environment delivers resources, influence on demand, and finite limits.
23 - Environment delivers resources, influences production patterns, and finite limits.
24 - Environment delivers conditions which affect the efficiency, applicability, and life of technology.
25 - Environment is intertwined, with ecological relationships among all of its components.

reinforce the systems generalizations that were identified in the Invention phase.

As Figure 2 indicates, the focus is upon the "deliveries" which are made from one component to another in the matrix. These deliveries indicate impacts or influence, which may or may not represent causal relationships. For example, a specific piece of government regulation may cause utilities to act in a prescribed manner. On the other hand, the fact that utilities deliver energy to consumers does not "cause" consumers to consume this energy. The matrix is concerned with cumulative causation, the interaction of many components which ultimately generate an action.

The information in the boxes may take any form that is applicable to the problem being discussed, there is no need to convert every box to a common denominator. One box may contain "hard" information on the total dollar flows from consumers to suppliers, the next may contain a qualitative statement about public perception of regulatory effectiveness, the next may contain energy efficiency information on new consumer appliances, the next on rates of cancer near atomic energy facilities. The degree of detail depends upon the knowledge of the group, the level of information needed, and the commitment to perform the required research.

As an introductory tool, this flexibility is valuable to the matrix. For example, it may be desirable to simply use the matrix as a visual aid in showing system complexity. The group could use its knowledge to identify the components. For those relationships where a delivery is made, a 1 could be placed in the appropriate cell. If there is no direct delivery, a 0 would be entered. The resulting pattern of 1's and 0's would give a visual image of system complexity to the group, without requiring a major commitment of time or money. This recognition of complexity could then guide the group in obtaining the information which is most pertinent to the issue.

The Social Fabric Matrix appears to be a useful tool in bringing systems thinking to a general audience. It requires no specialized systems knowledge, and is flexible enough to adapt to group needs without requiring an extensive commitment. Importantly, it incorporates an active-learning strategy which allows the group to utilize real-world experiences. Because the technique does not require specialized skills in modeling, it can be used immediately by the group members.

Using the matrix in approaching problems from a systems perspective does have a noticeable limitation - there is no mechanism for tracing changes in the system over time. Through the matrix, one can see that changes in technology, for example, will have impacts on several different cells. However, there is no way to discover the magnitude of those changes, how pervasive they will be throughout the system, or how long-lasting those changes will be. Therefore, the matrix alone is not sufficient to give a dynamic view of system behavior.

This weakness in the matrix is of course the great strength of system dynamics. One could argue that the two ideas are quite complementary. The matrix is a good, active methodological tool capable of introducing non-specialist audiences to the necessity of approaching problems with a systems viewpoint. It provides a method of analysis utilizing a system perspective without requiring specialized modeling skills. It is easy to use, and since it doesn't require computer time, is very inexpensive.

A side-by-side comparison of the two methods in Figure 3 shows their complementary nature, for the weakness of one is the strength of the other.

Figure 3

SOCIAL FABRIC MATRIX	SYSTEM DYNAMICS
STRENGTHS	WEAKNESSES
1. EASILY UNDERSTOOD BY USERS	COMPLICATED, REQUIRES COMMITMENT
2. IMMEDIATE USER PARTICIPATION	REQUIRES TRAINING, WHICH IS NOT ALWAYS AVAILABLE
3. FLEXIBLE, AMENABLE TO A VARIETY OF COMMITMENTS	SUCCESSFUL APPLICATIONS REQUIRE CONSIDERABLE COMMITMENT
4. VISUALLY CONCISE	VISUALLY, CAN CONFUSE A GENERAL AUDIENCE
5. REQUIRES NO PRIOR SYSTEMS KNOWLEDGE	BASED UPON CAUSAL LOOP RELATIONSHIPS WHICH ARE UNFAMILAR TO THE AUDIENCE
WEAKNESSES	STRENGTHS
1. STATIC APPROACH	DYNAMIC APPROACH
2. NO WAY TO TRACE IMPACT OF POLICY PROPOSALS	SIMULATION OF VARIOUS SCENARIOS
3. NOT DIRECTLY TRANSFERABLE TO COMPUTER OPERATIONS	DYNAMO LANGUAGE
4. AMBIGUOUS LANGUAGE POSSIBLE IN DESCRIPTION OF COMPONENTS	REQUIRES SPECIFIC MODELING STATEMENTS
5.	VISUALLY IMPRESSIVE

In those cases where the group chooses to go beyond the matrix, a system dynamics model could be constructed. While the variables in this model would not match the components identified in the matrix, the modelers would still benefit from its construction. First, active participation in developing the matrix would give many members of the organization an introductory lesson in systems thinking, thus performing a valuable "consciousness-raising" activity. Also, some of the information contained in the matrix could be incorporated into the dynamic model. For example, the matrix might contain information on the efficiency ratings of old and new appliances. The modeler could incorporate this information into his work very easily. Construction of the matrix should give clients a sense of the complexity facing the modeler, which, through increased understanding, should make them more responsive to the modeler's requests for information. From this short discussion, the potential value of the matrix as an educational tool in building systems thinking is apparent.

CONCLUSION

The transition to a "systems age" seems well under way, but progress is not evenly distributed. Refinements in methodology, and application of the new methods to specific problems has understandably drawn the lion's share of attention from systems scientists. While system dynamics has made tremendous strides in describing system characteristics, there are warning clouds on the horizon.

All too often, when the modeler leaves, the system thinking leaves as well. Or, as Senge says: "The benefits of even highly successful applications often prove only temporary, as policymakers drift back into old ways of thinking and operating." Even more chilling is his later statement: "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 of no case where it has occurred pervasively within an organization." (Senge, 1984, p. 88).

One could argue that the practitioners of system dynamics may have overlooked the importance of the long-term development of systems thinking by focusing on the short-term expediency of "answering the client's questions." By now, we know what happens to a system when short-term expediency takes precedence over long-term needs.

It is unreasonable to expect the general public to become systems experts, yet it is also impossible to see how system dynamics can have any real impact until the systems perspective is widely adopted. System scientists need to use effective educational tools like the Social Fabric Matrix to increase public awareness, thus aiding that long-term shift toward systems thinking that is so important to our future.

> The ultimate end . . . is not knowledge, but action. To be half right on time may be more important than to obtain the whole truth too late.
>
> Aristotle

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