"Open" Systems, Closed Minds

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ABSTRACT

System Dynamics has not achieved widespread recognition as a paradigm of substance in the business-related disciplines of Strategic Management, Organization Behavior, Organization Theory, or Operations Management. One reason for its slow acceptance by academicians in these fields and related social sciences may lie in the specialized meanings and usages attached to common words by the System Dynamics lexicon. Words such as "open," "closed," "feedback," and "structure" -- used differently than established scientists might expect -- may create perceptions that System Dynamicists simply don't understand systems theory. Writers in the field need pay special attention to the semantic implications of their presentation.

INTRODUCTION

The human legacy of feedback thinking, as traced by George Richardson (1991), covers some two millennia of practical inventions, two centuries of technological application, 100 years of analytic exploration, and 50 years of modern development. Richardson documents the growth of two quite separate threads of modern feedback thought, originating independently in cybernetics and in servomechanisms theory. These competing threads often use the same words with different definitions, without recognizing either that they represent different schools of thought or that they use different languages.

In the cybernetics thread, Richardson finds (pp 332-341), systems thinking begins with an equilibrium model, subject to exogenous disturbances and relying on homeostatic mechanisms to restore balance. Discrete stimuli from the environment are taken as causing the system to respond. The system's internal causal mechanisms are believed unobservable or beyond comprehension, so attention is concentrated on measurement of discrete inputs and resulting behavior. Systems are described in verbal terms, and complex social systems are seen to be capable of self-change: they can evolve, or "re-write" their internal structure. Dynamic behavior stems from the randomness of events, and management's problem is to anticipate and compensate for these disturbances.

In the servomechanisms thread, in contrast, systems thinking begins with a dynamic model, subject to exogenous disturbance but capable of departing from equilibrium and generating its own behavior through the interaction of internal forces. Environmental stimuli may stress the system, but they are not necessary to cause behavior. Internal causal mechanism are explicitly represented. Systems are described as quantitative, continuous relationships between variables arranged in positive or negative feedback loops, where nonlinearities can produce differing modes of system behavior without changing the basic model structure. Dynamic behavior stems from the feedback structure, and management's problem is to understand how its policies influence internally-generated behavior.

System Dynamics as an organized body of knowledge and practice clearly falls within the servomechanisms thread as described by Richardson. Yet the field has not achieved widespread respect in other disciplines. "The influence of this [servomechanisms] thread on feedback thinking in the social sciences appears to be slight compared to the influence of the cybernetics thread," says Richardson (1991, p 313). "The tendencies of thought that characterize this thread have not spread as widely..." (p 271). This paper examines one possible reason for the failure of the servomechanisms school of thought -- more specifically, of the System Dynamics school of thought growing from the writings of Forrester -- to penetrate the main stream of academic thinking.

THE PROBLEM

From the standpoint of the field's own professionals, the desired state is one where System Dynamics is widely recognized, understood, and accepted as an appropriate approach for analysis of complex nonlinear systems. In the ideal scenario, universities would vie for outstanding faculty capable of teaching the field; doctoral candidates could choose between prestigious teaching posts and lucrative practitioner positions; masters and bachelors graduates could look forward to influential positions in policy analysis and planning.

The current state of the system is not measured on any rigorous basis, but most System Dynamics people will agree the desired state is far removed from the present. Although the approach is appreciated by many in industry (as witnessed by the number of small consulting firms blossoming in the Boston area), it is far from achieving recognition in academic circles, especially in the United States. However, the field is growing, even if from a very small base. Given patience and a publicized base of successful applications, recognition should come. In other words, there is no real problem.

Some in the field point to Thomas Kuhn's *The Structure of Scientific Revolutions* (1970) to explain the slow progress of System Dynamics. Kuhn wrote that new paradigms ascend to prominence in an intellectual field only when existing science recognizes anomalies that cannot be explained by old theories. However, in a recent paper in *Science*, Lightman and Gingerich (1992) suggest that anomalies may exist for a very long time before people take them seriously. Only when a new paradigm is shown to <u>explain</u> a widely-recognized anomaly does the established field begin to respond, they say.

I suggest there is a problem for System Dynamics, and its professionals can influence the field's rate of acceptance. If they are to explain anomalies unresolved by existing science, they must do so in terms the establishment scientists can readily understand. They must recognize the vital role of communications across intellectual boundaries, and take pains to write in the language of the target audience.

The hypothesis of this paper is that faculty members in all the social sciences and their related business disciplines already have what they believe is an adequate grounding in systems theory and see little need to alter what they "know." Their operative paradigm is anchored in the cybernetic thread of feedback theory identified by Richardson. They studied systems theory in their own doctoral programs and seminars, and they have trained thousands of doctoral candidates in those same systems beliefs since receiving their own degrees. They share a common vocabulary and common beliefs about such elementary concepts as cause-and-effect. They are the essence of what Kuhn called "established science." Further, they are the majority viewpoint, and it is naive to expect them to take the initiative in giving System Dynamics "equal time."

When System Dynamics writers attach different meanings to common words -- words already "owned" by established systems thinkers -- it should not be surprising that the establishment misunderstands. We might expect many faculty to simply ignore the System Dynamics paper, assuming its author didn't know enough about systems to merit serious attention.

Like Paul Newman in the film, *Cool Hand Luke,* what we have here is a classic "failure to communicate." Luke paid with his life for his refusal to acknowledge the dominant norms and definitions of those in power.

DEFINITIONS IN THE CYBERNETICS THREAD

The pertinent set of definitions for concepts in the cybernetics thread of feedback thinking must be drawn from old literature -- from the books studied by the people most influential now in the scientific fields we would like to influence. Those faculty members are the full professors, the textbook authors, the dissertation chairs, the hiring committees, the editors, the referees -- all the senior faculty who lead opinion in their disciplines. Those are people whose operating definitions of systems theory were formed in the 1960s and 70s; it is the literature they studied that we must look to.

This paper takes the business-related fields of study -- Strategic Management, Organization Behavior, Organization Theory, Production/Operations Management, etc. -- as the domain most pertinent to System Dynamics. In these fields, an extremely influential book at the time of interest was *The Social Psychology of Organizations*, by Katz and Kahn (1966 and 1978). A full generation of management scholars learned its basic system concepts and definitions from this book. Since those are the scholars whose models System Dynamics seeks to change or replace, it is necessary for us to understand the viewpoint they bring to conversations or debates about systems.

Ten Characteristics of "Open Systems"

Katz and Kahn fall squarely within the cybernetics thread, crediting their major source (1978, p 22): "This model of an energic input-output system is taken from the open system theory as promulgated by von Bertalanffy (1956)." Katz and Kahn defined their "energic input-output system" as marked by ten distinct characteristics (1978, pp 23-30):

1) Importation of energy from the system's environment;

2) Throughput, or work, by the transformation of energy or the reorganization of inputs;

3) Output: the export of something to the environment;

4) Cycles of events: for example, from production to the product's marketing, to the collection of revenues, to the purchase of additional raw materials, and back to production;

5) Negative entropy, importing more energy than expended, permitting storage of energy and growth;

6) Information input, negative feedback, and the coding process;

7) The steady state and dynamic homeostasis: continuous energy flow and stable characteristics of the system's equilibrium;

8) Differentiation: movement toward greater specialization;

9) Integration and coordination: development of "fixed control arrangements." (The other nine points were identical in the 1966 edition (pp 19-26); this point was added in 1978.)

10) Equifinality: a system can reach the same final equilibrium state from different initial conditions and via different paths.

To a System Dynamicist, this may seem a strange list of the defining characteristics of a system. It is drawn directly from von Bertalanffy, whose work in biological and chemical systems was aimed at resolving a pressing philosophical issue of the 1930s and 40s: how could systems develop, organize, and grow in the face of the second law of thermodynamics? Von Bertalanffy himself cautioned against applying open systems theory to sociocultural systems (1968, p 28), but that caution and the other conditions he placed on his original concepts were disregarded by the social scientists Katz and Kahn. It is useful to elaborate on the above list of characteristics, to demonstrate how far afield from System Dynamics usage are the assumptions and definitions of the cybernetics thread.

System Boundaries

The first three characteristics of Katz and Kahn's open systems imply boundary definitions, which the authors amplified in a number of passages. "Our basic model...imports energy, transforms it, and exports a product to the environment that is the source for re-energizing of the cycle" (1978, p 55).

"...the social system is more open than physical systems; it must constantly import both production and maintenance materials [both raw materials and human resources]" (1966, p 31)

"System boundaries refer to the types of barrier conditions between the system and its environment which make for degrees of system openness....Boundaries are the demarcation lines...for admission of members into the system and for other imports into the system. The boundary constitutes a barrier for many types of interaction between people on the inside and people on the outside..." (1966, p 60).

"Social systems will move...toward incorporating within their boundaries the external resources essential to survival" (1978, p 28).

System Structure

The fourth defining characteristic implies the cybernetics concept of structure as embodied in cycles of discrete events: "Social systems have a structure, but it is a structure of events rather than physical parts." (1966, p 69)

"Structure is to be found in an interrelated set of events that return upon themselves to complete and renew a cycle of activities." (1978, p 24; Katz and Kahn here credit F. H. Allport and James Miller).

"The basic method for the identification of social structures is to follow the energic chain of events from the import of energy through its transformation to the point of closure of the cycle." (1978, p 25).

Negative Entropy

Katz and Kahn's fifth characteristic derived directly from von Bertalanffy's efforts to settle the debate over how systems could self-organize and grow. The importation of energy, information and materials across system boundaries was seen as counteracting the natural process of entropic decay. To von Bertalanffy, it was important to discredit the unscientific idea of "vitalism," which endowed all enduring or growing systems with some life force of their own.

Feedback

Richardson has documented the cybernetics thread's use of "feedback" as oriented toward communications and message handling, as opposed to the servomechanisms usage of interrelated causal linkages. Katz and Kahn's sixth characteristic links feedback with information inputs and coding processes.

"The simplest kind of informational input found in all systems is negative feedback. Information feedback of a negative kind enables the system to correct its deviations from course....to keep the system on target." (1978, p 26).

The reference to "information feedback of a negative kind" suggests the authors' readiness to equate negative feedback with "constructive criticism," as is frequently found in the literature of interpersonal behavior and organization development. As Richardson noted, the cybernetics thread is not conscious of positive feedback or self-reinforcing "vicious circles."

The Steady State and Dynamic Homeostasis

Open systems theory was originally based on tightly constrained, rigorously defined, continuous-flow chemical systems, where a steady state could be mathematically described. In its application here by Katz and Kahn, the concept has lost much of its precision. "Steady state" seems to take on some aspects of "consistent behavior." The authors were aware of the internal inconsistency between an equilibrium model and a universe of growing systems. They drew on Kurt Lewin's field theory (1951) to reconcile the differences.

"...in counteracting entropy, these [homeostatic] systems move toward growth and expansion. This apparent contradiction can be resolved, however, if we recognize the complexity of the subsystems and their interaction in anticipating changes necessary for the maintenance of an overall steady state." (1978, p 26).

"In terms of Lewin's quasi-stationary equilibrium, the ups and downs of the adjustive process do not always result in a return to the old level. Under certain circumstances a solidification or freezing occurs during one of the adjustive cycles. A new base line is thus established and successive movements fluctuate around this level, which may be either above or below the previous plateau of operation." (1978, p 28).

Differentiation and Integration

The eighth and ninth characteristics of open systems appear to be an effort to embrace the contingency theory model of Lawrence and Lorsch (1967), published concurrently with Katz and Kahn's early work.

Equifinality

Von Bertalanffy's original concept of equifinality was a mathematical statement of general transport equations, stating that the rate of change of a variable in the open system is equal to the velocity of transport through the system plus the rate of production of the variable by the system. Provided that both the velocity and the production rates are linear with respect to the variable, and provided both are independent of time, von Bertalanffy said, then a steady state attained by the system has a value "equifinal" or independent of the initial conditions.

Equifinality in its original conception was a severely constrained system condition -- a necessary condition for the system to qualify as "open." The constraints, however, do not survive in the modern social science interpretation.

System Dynamics

One further definition from the Katz and Kahn treatment is essential to this paper. The authors define "system dynamic" as the maintenance of equilibrium in social organizations by constant adjustment and anticipation.

"The operation of system dynamics can be seen in the acquisition and extractive mechanisms employed by systems and subsystems. Much of the organizational literature...is strangely silent...about how a social system acquires the input necessary to maintain itself and carry on its functions" (1966, p 67). The authors go on to suggest that competition, in many dimensions, is the answer.

IMPLICATIONS OF THE DOMINANT PARADIGM

It is tempting for System Dynamicists to evaluate the Katz and Kahn characteristics, to refute or deny their applicability, or to ignore them entirely as unworthy of attention. I suggest these are the same reactions cybernetics-trained scientists might experience on reading one of our manuscripts. They would see we used words incorrectly, failed to understand the most basic concepts, and failed even to see that we could not see. Some of them might conclude our material was not worth reading.

It is vital to recognize that the Katz and Kahn definitions represent the dominant paradigm in the social sciences, or at least in the business-related descendants of the social sciences, as it was studied by the generation of senior academics who now stand in judgment of our work. To the extent the definitions here linger in the perceptions, the writing, or the teaching of today's opinion leaders, System Dynamics suffers an immense handicap in presenting its message. The words we use -- even the name of our field -- may evoke negative responses wholly unrelated to the content of our work.

For example, our use of "closed" loops is often taken as indicating our work is restricted to closed systems -- systems of utterly no interest to scholars in the cybernetics thread (or to us). This confusion is seen in the early work of Stafford Beer (1959) as reported by Richardson (p 184). It has also arisen frequently in conversations between disciplines; a major figure in international behavioral science reported to me in 1975 he had once asked a graduate student to look into System Dynamics, but had lost interest on hearing the method dealt only with closed systems.

Richardson see less conflict and more potential for convergence between the cybernetics and the servomechanisms threads of feedback thinking than do I. "Over time," he says, "...as feedback ideas become more persuasive in the social sciences, we should expect a blending of the two threads. Some natural selection process ought to take place, guided by whatever governs the ecology of ideas" (1991, p 166). All those with an interest in System Dynamics will concur: of course the threads ought to converge. But we must recognize that scientists of the established point of view will see no reason to "blend" with us. Richardson hints at no mechanism for bringing about the hoped-for convergence.

He does recognize the short-term disadvantage of System Dynamics. ":In the long run, the feedback ideas that persist are likely to be those with the most promise. But there seems to be no guarantee that in the short run less promising aspects of a new view will not be selected. The prevailing wisdom will strengthen certain aspects of a new view, those that are most easily assimilated, even if they will prove in the long run to be the less promising aspects." (1991, p 286).

For members of the prevailing school of thought, non-linear, multi-loop continuous system representations are not easily assimilated. They are a foreign language.

Management practitioners, on the other hand, are not handicapped by training in the existing science. They recognize the applicability of the System Dynamics approach. This is both a blessing and a curse. Practitioners provide employment for our graduates, but they also lure promising students away from academic careers where they could, by teaching, increase the creation rate of dynamic modelers.

TOWARD RESOLUTION OF THE PROBLEM

This paper is based on opinion and assumption as much as on analysis. I assume that nearly all management scientists, regardless of discipline, are familiar with at least a superficial appreciation of "open systems theory" and accept it at face value, without conscious thought (although most do not attempt to use it in their own work). I assume the established scholars see little or no need to invest time and effort in re-examining their systems concepts. I assume they form quick judgments about new ideas, based on their apparent ease of assimilation into the existing body of knowledge and their apparent utility to the scientist.

If these assumptions hold, then arguments posed as confrontational debates between paradigms are unlikely to attract opponents of stature. Explanations detailing closed loops of cause and effect relationships will only close the minds of the audience. Protestations about positive feedback will produce little response, because the concept has no corresponding point in the cybernetics thread. Similarly, nonlinearities are not necessary to explain system morphogenesis, if the audience believes systems are capable of self-reorganization. All the fundamental aspects of System Dynamics that make the field attractive to its proponents, make it irrelevant or trivial to holders of the dominant paradigm.

How, then, can we influence the acceptance rate of the servomechanism-based approach? I suggest the first imperative is to recognize the mind-set of the cybernetics-oriented scholars, and to phrase our communications with them in language that links to their own frame of reference. It should not be necessary (and it is surely difficult) to teach them the details of dynamic modeling. It is unrealistic to try to "convert" them to our enlightened point of view.

Rather, we can avoid direct confrontation and recognize we are the minority. As such, it is in our interest to consider the community of scholars as a customer, to whom we need to sell ideas. We could position System Dynamics in the intellectual marketplace as a vital tool for addressing a class of systems not easily handled with existing theory. (We ourselves may be convinced that class is all-encompassing in scope, but there is no need to convince the majority of that point.) We could seek out and use more descriptive terms for our work -- using words linked to positive images in the management disciplines. And we could do this, in my opinion, without compromising the integrity of System Dynamics in any way. The key lies in recognizing that many (perhaps most) of the established scholars are non-quantitative thinkers, unequipped to judge the merits of a technique at the detail level. They need explanations at their own level of comprehension and analysis. As customers, they deserve no less.

Systems of Bounded Rationality

For example, we might tell others we are concerned with a subset of open systems, called perhaps "Systems of Bounded Rationality." Such systems, we could say, fall outside the strict domain of economic analysis because they incorporate decision-makers' perceptions and their nonlinear responses to stimuli originating both inside and outside the system. Since the problems we address are poorly defined, our methods are aimed first at theory-building, and then at testing the theories for internal consistency and potential utility by the client. We are conscious of the

Such a description does no injustice to either System Dynamics or to Herbert Simon, whose phrase (1945) so aptly describes the kind of systems we are good at. This description might help others recognize the unique niche of System Dynamics, without implying that all other techniques are now obsolete and without creating defensive reactions. Indeed, any set of tools proclaiming success at treating intractable problems might be widely accepted.

Many other approaches might also be devised, to gain credibility for the field. The important first step is to recognize within System Dynamics that our language is not common, even though other scientists use the same words. We must recognize that the paradigmatic debate is not restricted to proponents of the cybernetic and the servo-mechanisms traditions; it extends to the whole community of established academic professionals. The vast majority of those scholars would be intensely disinterested in the details of debate between competing systems points of view. They know enough about open systems theory to recognize it when they hear it, but not enough to judge technical merit. On technical issues, they will follow the leaders of conventional wisdom.

I suggest that System Dynamics might increase its rate of acceptance by adopting a niche strategy, in which it complements existing techniques by demonstrating success at theory building and testing in specialized problem applications. Scores of such applications are documented in the literature, but they are typically presented on a technical level or as confrontational invitations to combat. If recognition can be achieved by presenting these cases as evidence for competence in a small niche, then the future question becomes one of enlarging the niche.

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