DOCUMENT RESUME

ED 125 911 SE 021 167

AUTHOR Maccia, Elizabeth S.; Maccia, George S.
TITLE The Logic of the SIGGS Theory Model.
PUB DATE Apr 76
NOTE 22p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, California, April 19-23, 1976)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Educational Research; Graphs; *Mathematics; *Models; *Research; *Systems Analysis; Systems Approach
IDENTIFIERS *SIGGS Theory Model

ABSTRACT

This paper describes the SIGGS Theory Model as it applies to educational systems. This model, designed to simulate a wide variety of systems, uses sets (S), information (I), graph theory (G), and general systems (GS). The educational system is viewed as a set; in one example this set consists of teacher, student, curriculum, and setting. This paper describes the mathematical relationships among variables and the general approach of the model. (SD)

THE LOGIC OF THE SIGGS THEORY MODEL

by
Elizabeth Steiner Maccia
George S. Maccia
Indiana University

American Educational Research Association
San Francisco
April, 1976

INTRODUCTION AND ABSTRACT

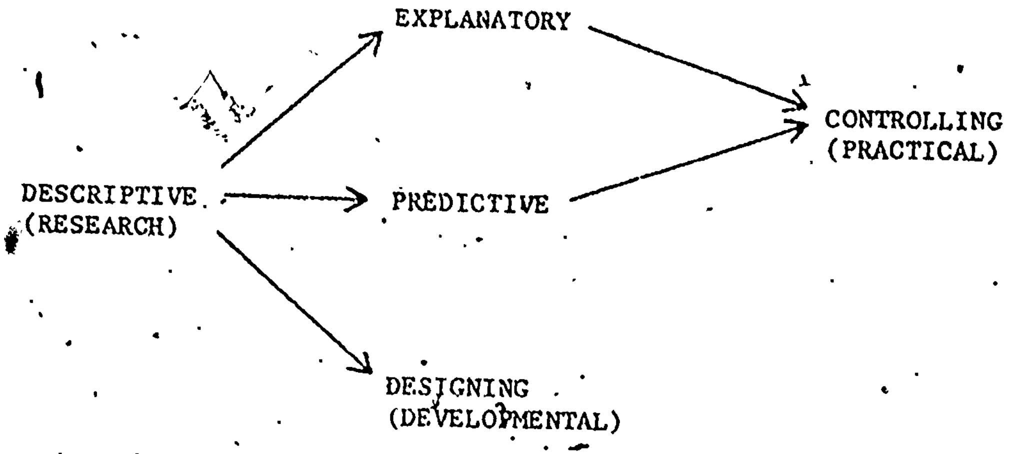
In this paper, the logic of the SIGGS Theory Model is set forth. To set forth logic is to explicate order, i.e., function with its attendant structure. Thus, the paper is constituted of two parts: one treating SIGGS' pragmatics and the other SIGGS' semantics and syntactics.

PART 1: SIGGS' PRAGMATICS

The SIGGS Theory Model has been formulated in order to provide a conceptual paradigm for describing any system whether it be physical or biological or hominological (1). Consequently, SIGGS is for describing atoms as well as educational organizations. Since SIGGS is for devising generalizations which characterize the properties of any system and the interrelations of these properties, it is a general system theory (2).

Given SIGGS' inherent descriptive function, instrumental functions obtain. When one can characterize systems, one can devise them. Understanding permits designing. Also when one can characterize systems, one can account for their being and can foretell what they will be. Understanding also permits explanation and prediction. When one can diagnose or prognosticate, one can direct the course of events. Understanding, therefore, through explanation and prediction permits control.

Schema 1 summarizes the pragmatics of the SIGGS Theory Model. The model functions in research to generate knowledge about systems. From this inherent descriptive function arise three other functions: explanatory, predictive, and designing. Two of these three instrumental functions give rise to yet another instrumental one, i.e., the explanatory



SCHEMA 4: PRAGMATICS OF SIGGS

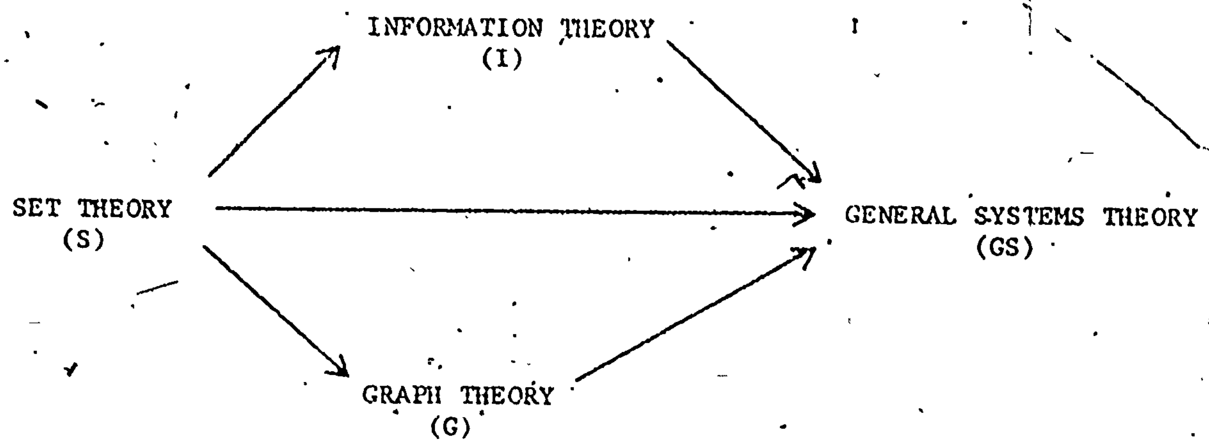
and the predictive functions give rise to the controlling one. This last mentioned function is the practical one, while the earlier mentioned designing function is developmental in nature.

PART 2: SIGGS' SEMANTICS AND SYNTACTICS

The SIGGS Theory Model was formed by integrating set (S), information (I), and graph (G) theories with general systems (GS) theory. This integration is depicted in Schema 2. Because set theory is basic to both information and graph theories, in the depiction set theory is related to general systems theory not only directly but also indirectly through information and graph theories.

Set theory is a mathematical theory which characterizes sets. 'Set' is a primitive term, and so cannot be defined. However, one can explicate it intuitively by means of alternative referents. A set can be thought of as a collection, a class, an aggregate, a group, etc. From these alternative referents, a set usually, although not always, has something within it which could be considered as belonging to the set: the objects of the collection, the members of the class, the points of the aggregate, the components of the group, etc. That which belongs to the set is called 'an element'. Moreover, the objects, members, points, components, etc. can themselves be taken as sets of elements; and if they are so taken, then the collection, the class, the aggregate, the group, etc. can be thought of as families of sets.

The use of set theory can give precision to von Bertalanffy's definition of system as a "complex of elements standing in interaction" (3).



SCHEMA 2: THE SIGGS THEORY MODEL

The complex of elements is interpreted as a set, and hence as elements forming a unit. To illustrate, teacher, student, curriculum, and setting form an educational system (4). In set theoretic notation:

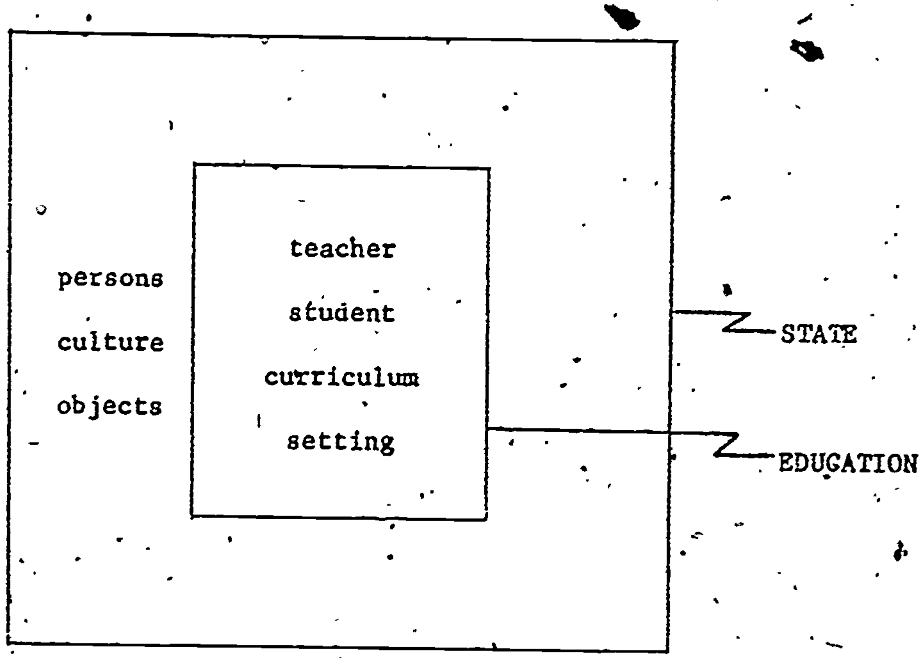
$$E = \{t, s, c, g\}$$

where 'E' stands for educational system
't' stands for teacher
's' stands for student
'c' stands for curriculum
'g' stands for setting

In a set, the elements form a unit within a universe of discourse. To continue the illustration, an educational system can be considered in the context of the state. Also it can be considered within other universes of discourse, e.g., the home or the church. But it cannot be considered within any universe of discourse. The unit must be consistent with the universe of discourse. It does not make sense to consider an educational system in the context of a molecule, but it does to so consider an atom.

Given a set within a universe of discourse, the universe which is not the set is its complement. This set theoretic notion of complement gives precision to a system's surroundings or to what is not system. What is not system is called 'negasystem'. In the illustration of an educational system within the context of the state, the surroundings consist of persons, culture, and objects within the state but not within the educational system.

Schema 3 summarizes the illustration of the use of the set theoretic notions in delineating a system and its surroundings. It should be noted that what is taken as a component in one universe of discourse can be taken as a system in another. Changing the universe of discourse from the



SCHEMA 3: EDUCATION AS A SYSTEM

state to education, the student can be taken as a system rather than as a component. One would then delineate the components within the student, i.e., the affective, conative, and cognitive properties. These properties would be the components of the system and the components other than the student would be those of the negasystem. Within education one is not limited to the student as system. The teacher or curriculum or setting or any combination of two or three components of education could be taken as the system. The negasystem would be changed accordingly. The figures in Schema 4 show within education three different system perspectives.

Set theory not only gives precision to "complex of elements" but also to "standing in interaction". The precision is obtained by utilizing the set theoretic definition of 'function'. Since a function from one set into another is constituted by an association of elements in one set with those in the other, standing in interaction can be interpreted as a mapping of the set into itself, and hence as affect relations. For example, the affect relations between the components of the educational system are constituted by the mapping of teacher, student, curriculum, and setting into teacher, student, curriculum, and setting. That is to say, where there is association between a teacher property and a student property, the teacher property affects the student property or the student property is a function of the teacher property. See Schema 5.

Set theory is also utilized to give precision to conditions on the system over and above the essential ones treated above. It is used explicitly to give precision to system characteristics such as sameness within

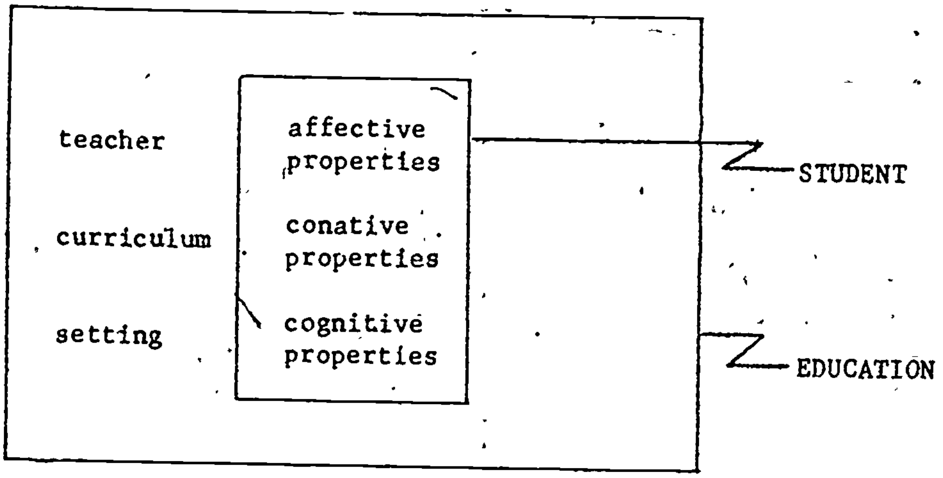


Figure 1: Student as System

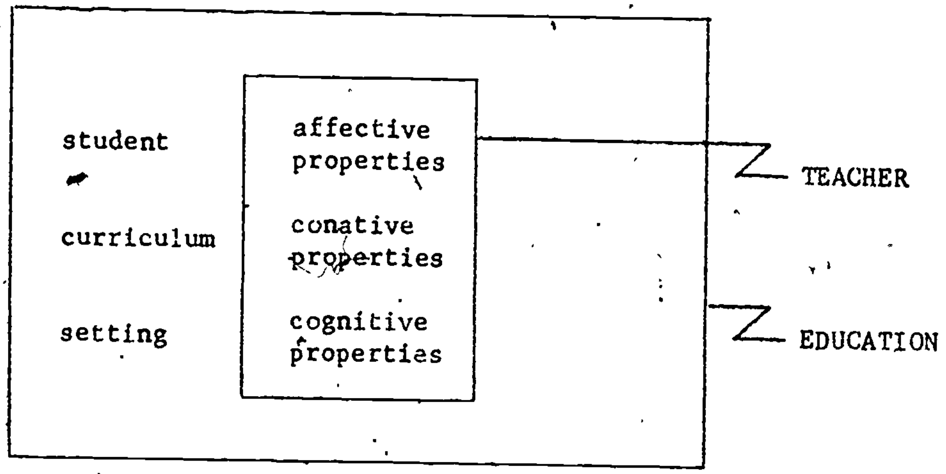


Figure 2: Teacher as System

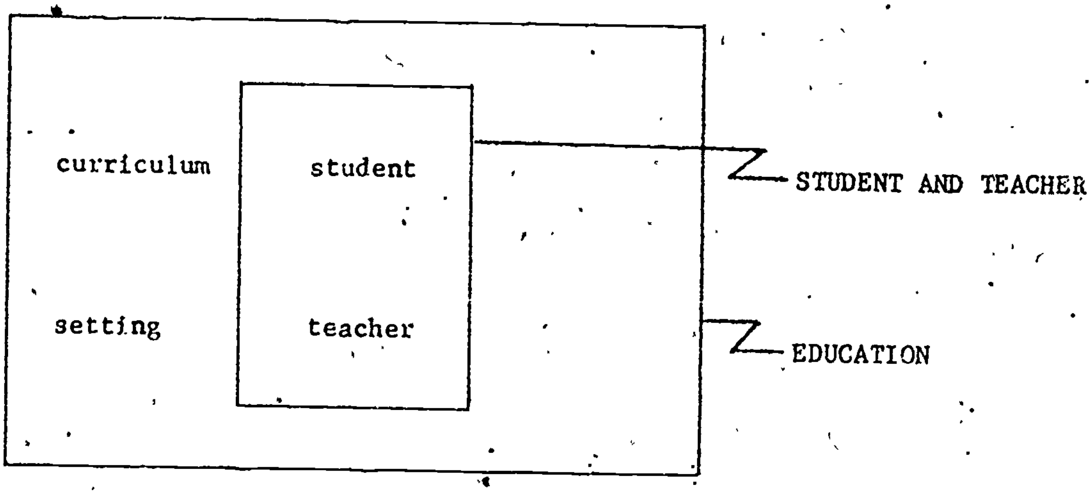
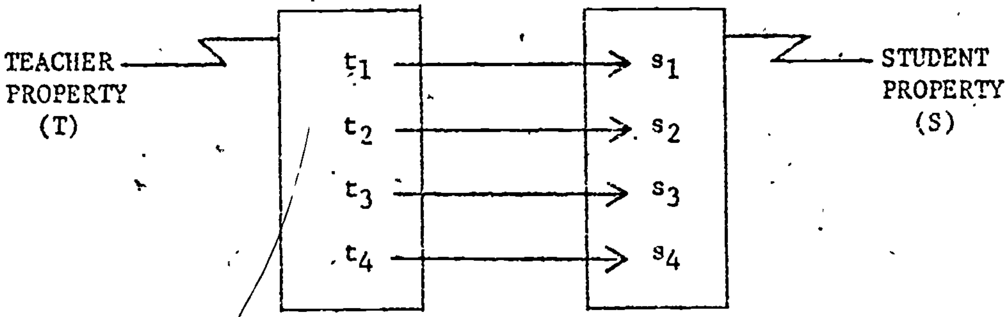


Figure 3: Pedagogic System

SCHEMA 4: SYSTEM PERSPECTIVES WITHIN EDUCATION



SCHEMA 5: FUNCTION OF TEACHER PROPERTY TO STUDENT PROPERTY

$$
\begin{aligned}
f:\ & T \longrightarrow S \\
\text{where}\quad T &= \{t_1, t_2, t_3, t_4\} \\
S &= \{s_1, s_2, s_3, s_4\} \\
f &= \{(t_1,s_1), (t_2,s_2), (t_3,s_3), (t_4,s_4)\}
\end{aligned}
$$

a system's structure. Such uniformity is set forth as an isomorphic mapping. An illustration in education would be uniformity in the curriculum. Set theory is used implicitly when information or graph theories are utilized for system characterization. This is so, because set theory is basic to both information theory and graph theory.

Digraph theory is mathematical theory which characterizes between pairs of points lines which can be directed. Figures can be utilized to explicate intuitively a digraph, as in Figure 4.

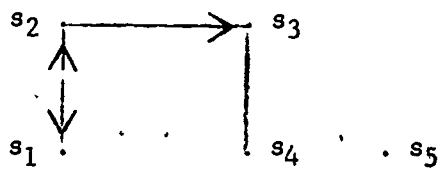


Figure 4

Figure 4 was constructed from points - s_1, s_2, s_3, s_4, s_5 - and lines, some of which are arrows. There are no lines between s_5 and the other points. Thus, s_5 is not connected to or paired with any of the other points. Where there is an arrow or arrows between two points, there is a directed connection or a pairing. Consequently, there is a directed connection or pairing between s_1 and s_2, s_1 and s_3, s_2 and s_1, and s_2 and s_3. Given only one arrow between two points, the directed connection is direct as in s_1 and s_2, s_2 and s_1, and s_2 and s_3. Where there is a line without an arrow, a directed connection will be assumed in one or the other direction or in both directions. (5) So a directed connection is assumed between s_1 and s_4, s_2 and s_4, and s_3 and s_4 or s_4 and s_3 or both. Since the line between s_2 and s_3 has an arrow, the direction is given from s_2 to s_3 and not from

s_3 to s_2. Therefore, s_3 is not paired to s_2 or s_1 and also s_4 is not paired to s_2 or s_1. To summarize, the graph in Figure 4 can be expressed in a matrix

$$\begin{array}{cc} & \begin{array}{ccccc} s_1 & s_2 & s_3 & s_4 & s_5 \end{array} \\ \begin{array}{c} s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \end{array} & \begin{Vmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1^* & 0 \\ 0 & 0 & 1^* & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{Vmatrix} \end{array}$$

where '*' indicates the possibility of one of the two entries being 0

and as a relation

$$(s_1, s_2), (s_1, s_3), (s_1, s_4)$$
$$(s_2, s_1), (s_2, s_3), (s_2, s_4)$$
$$(s_3, s_4) \vee (s_4, s_3)$$

From the matrix it can be seen that the total possible pairs of points in a graph of five points is twenty, and that the graph presented in Figure 4 has only seven or eight pairs out of the twenty.

By adding graph theory to set theory, the complex of elements which is a system is not only interpreted as a set but also as a set of points, and the standing in interaction which is a system is not only interpreted as functions but as directed lines. This added interpretation permits the utilization of properties of graphs to give precision to certain properties of systems. For example, a system would have complete connectedness if and only if all its affect relations were direct directed ones, i.e., direct channels from and to each component. The graph presented in Figure 4 is not completely connected. Rather it is disconnected. Figure 5 presents a

completely connected graph.

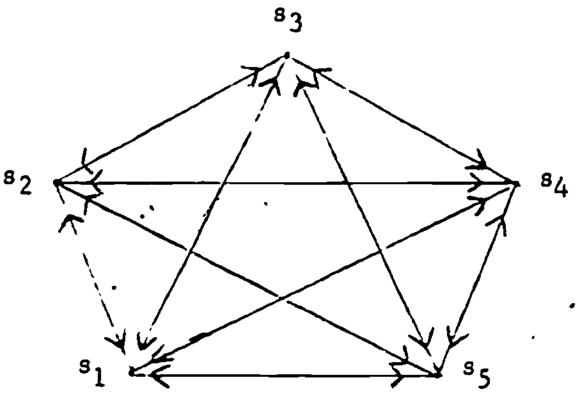


Figure 5

To illustrate the utilization of graph theoretic properties with respect to education, consider transmission of culture in a group consisting of a teacher and four students. Let the point s_5 represent the teacher, s_1, s_2, s_3, and s_4 the students, and lines between the points transmission channels. Figure 4, therefore, represents a system in which there is no connection between the teacher and any of the students. The teacher does not transmit culture. On the other hand, Figure 5 represents a system in which there is a connection between the teacher and each of the students. The teacher does transmit culture. However, each student is in the same position as the teacher in regard to the transmission of culture. (6)

In order to treat transmission, information theory must be used as well as graph theory. Information is the characterization of occurrences. This fits in with the ordinary notions of information. When one is informed, one knows or can characterize what is happening. To characterize occurrences is to classify them according to categories. But for describing transmission the condition of selectivity must be placed upon information.

There must be uncertainty of occurrences at the categories. Uncertainty of occurrences is explicated in terms of a probability distribution. In a system context, if there is uncertainty with respect to an occurrence of a system component at a category of a classification of the system components, then the probability at the category can be neither 1 or 0 but must be less than 1 or greater than 0. Consequently, there must be at least one alternative category for the occurrence of the component, since the sum of the probabilities must be equal to 1. Alternatives indicate selection. This selective sense of information also fits in with the ordinary notions of information. One needs information only when one does not know something. We must be uncertain or faced with a choice between alternatives. Complete knowledge involves no uncertainty or information.

The basic information function is designated by 'H'. By summing over the amount of information associated with each selection, weighted by the probability that the selection will occur, the value of H can be obtained. To state the matter more precisely, H(C) is the average uncertainty per occurrence with reference to the classification C; it is the average number of decisions needed to associate any one occurrence with some category c_i in C, with the provision that the decisions are appropriate; it is a function of the probability measures in C:

$$H(C) = \sum_{i=1}^{n} p(c_i) \log_2 \frac{1}{p(c_i)}$$

The measure for joint uncertainty would be

$$H(C_{IJ}) = \sum_{i=1}^{m} \sum_{j=1}^{n} p(c_i, c'_j) \log_2 \frac{1}{p(c_i, c'_j)}$$

The measure for conditional uncertainty would be

$$H(C_I|C_J) = \sum_{i=1}^{m} \sum_{j=1}^{n} p(c_i, c'_j) \log_2 p(c_i|c'_j)$$

The three H measures are related as follows:

$$H(C_I) + H(C_J|C_I) = H(C_{IJ})$$

The T measure is the amount of shared information:

$$T(C_I, C_J) = H(C_I) + H(C_J) - H(C_{IJ})$$

The following properties of a system can be interpreted in terms of H:

toput, TP, which is information of the system's surroundings (the negasystem) available to the system for its selection, i.e., the system's environment

input, IP, which is information of the system

storeput, SP, which is information of the system not available to its surroundings

fromput, FP, which is information of the system available to its surroundings

output, OP, which is information of the system's surroundings

The sharing of information, T, as well as being separated by time intervals give meaning to the following system properties descriptive of information transmission:

feedin, FI, which is a transmission of information from the system's surroundings to the system

feedout, FO, which is a transmission of information from the system to its surroundings

feedthrough, FT, which is a transmission of information from a system's surroundings through the system back to its surroundings

feedback, FB, which is a transmission of information from the system through its surroundings back to the system

Schema 6 displays these information theoretic properties with respect to a student system.

In considering these information theoretic properties the extension of the cybernetic model through SIGGS (7) should be noted. In the context of the non-extended cybernetic model shown in Figure 6

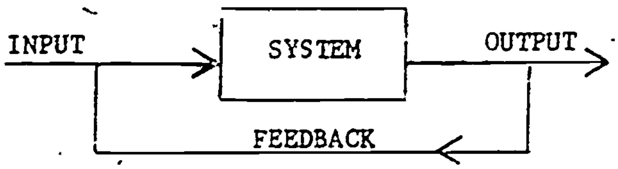
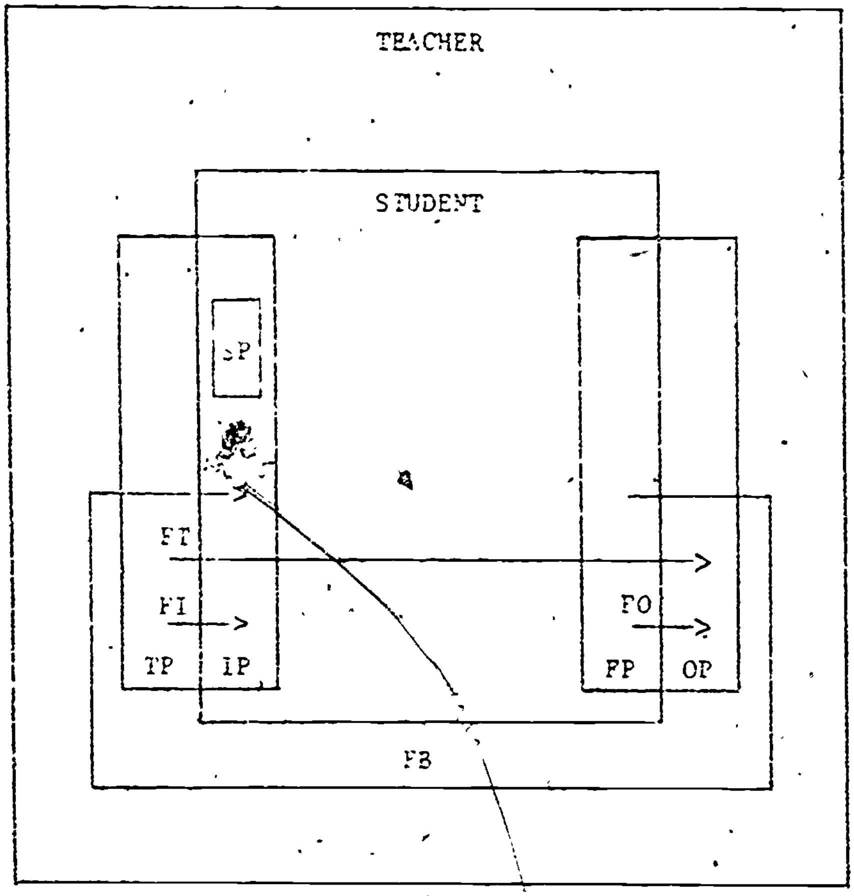


Figure 6

no descriptions of system-surroundings interactions are possible. Given SIGGS, toput and a new sense of output are added to input and output which is now interpreted as fromput. Determination is now possible not only of what the system takes in and what is available from it but also of what the system's surroundings take in and what is available to them. Feedin, feedthrough, and feedout are added to feedback which is now interpreted as flow from output to input. Transmission from and to both the system and its surroundings can be characterized.



SCHEMA 6: INFORMATION THEORETIC PROPERTIES OF A STUDENT SYSTEM

Also these information theoretic properties should not be given a mechanistic interpretation. Input cannot be viewed as determining output, i.e., input and output viewed as a functional relation in which input is the independent variable and output is the dependent variable. The model of system shown in Figure 7

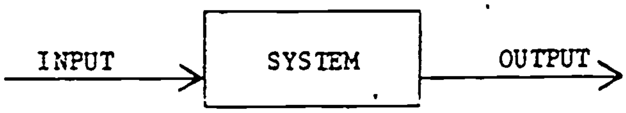


Figure 7

is mechanistic and inadequate. What is outputed or what the system is to do, its function, determines what is to be inputed or what the system is to be. Thus, this model's linearity and additivity must give way to the functionality of SIGGS. (8)

To illustrate the difference between a mechanistic interpretation and a general systems one, consider the following table relating the teacher as environment to the student as system:

		Student (S)					
		1	2	3	4	5	6
Teacher (T)	1						
	2						
	3						
	4						
	5						
	6						

In a mechanistic interpretation in which teacher action is taken as input causing the output student action, observed frequencies inserted in the above table would be in terms of some position, i.e., a precise location in a specified metric space. Each frequency of S or T would be taken as representing a unit of a line drawn in a certain direction in reference to

other lines. An intersect of teacher action and learner action would be a unit of a line surface that bounds the metric space. To estimate the causal connection between the input and output, computations such as Chi square would be utilized. Chi square computations compare the line surface given by mapping the observed distribution with the line surface generated by some expected distribution, i.e., random, Poisson, or another appropriate distribution.

In a general systems interpretation, the observed frequencies would be in terms of the joint occurrence of teacher action and student action where such actions are not taken as input causing output. The teacher action would not be viewed as input but as toput or information available to the student for selection. The student action would not be viewed as output but as input or information selected by the student from the toput. Estimation of the relation between toput and input would be made without reference to line surfaces taken as normal or appropriate. It would be made through a measure of the transmission of information, i.e., the information shared between the teacher and student, T(T,S), which is calculated as follows:

$$T(T,S) = H(T) + H(S) - H(T,S)$$

where H(T) is the amount of information in teacher action
H(S) is the amount of information in student action
H(T,S) is the amount of information in teacher and student actions taken jointly.

Obviously transmission is not taken in a directional sense. The general

systems interpretation is geometric rather than arithmetic. Interactions are taken as changes in patterns. The whole or the configuration is taken as the reality to be described.

FOOTNOTES

1. 'Hominological' was introduced by Elizabeth Steiner Maccia in 1963 (CONSTRUCTION OF EDUCATIONAL THEORY MODELS, Washington, D.C.: Cooperative Research Project No. 1632, Office of Education, U.S. Department of Health, Education, and Welfare) to characterize knowledge about human beings.

2. Von Bertalanffy announced general system theory in 1945. See Chapter 3 in von Bertalanaffy's GENERAL SYSTEM THEORY published by George Braziller, Inc. in 1968.

3. Von Bertalanffy, op. cit., p. 33.

4. 'Educational system' is not used in its restricted sense of a complex of interrelated schools, colleges, or universities. In this restricted sense, an educational system is a system of educational systems.

5. The result of such an assumption is the treatment of graph theory within the context of digraph theory. 'Di-' indicates that graphs consist of directed lines. Interchangeable usage of the terms, 'graph theory' and 'digraph theory', therefore, is permitted.

6. See "An Educational Theory Model: Graph Theory" in CONSTRUCTION OF EDUCATIONAL THEORY MODELS, op. cit., for further similar application of graph theoretic properties to a pedagogic system.

7. See our article, "Information Theoretic Extension of the Cybernetic Model and Theory of Education" in ADVANCES IN CYBERNETICS AND SYSTEMS, edited by J. Rose and published by Gordon and Breach in 1975. This article appeared also in THEORIE A METODA, Ustov pro filosofil a sociologii CSAV, Vol. VI, No. 1, 1974.

8. The Mechanistic Approach is contrasted with the General Systems Approach in our paper, "On the Contribution of General Systems Theory to Educational Research" to be published in the Proceedings of the 1976 Meeting of the Society of General Systems Research.