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ABSTRACT

The use of the systems approach in educational inquiry is not new, and the models of input/output, input/process/product, and cybernetic systems have been widely used. The general systems model is an extension of all these, adding the dimension of environmental influence on the system as well as system influence on the environment. However, if the theory model is changed, traditional statistical procedures may no longer be applicable and other mehtods should be used. The Set, Information, Graph, and General System Model (SIGGS) is a further extension of general systems in that set theory, information theory, and digraph theory are used as models to extend general systems theory. This paper further discusses the application of the SIGGS model and information statistics to the Indiana Behavior Management Systems (IBMS), an observation system concerned with teacher management of off task, deviant learner behavior, which was used in an evaluation of Programmed Reentry (of mildly handicapped children) Into Mainstream Education (Project PRIME). (BW)

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Application of SIGGS to Project PRIME:
A General Systems Approach
to Evaluation of Mainstreaming

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SIGGS: Set, Information, Graph, and General Systems Theory Model (E. S. & G. S. Maccia)

Project PRIME: An evaluation of Programmed Re-entry (of mildly handicapped children) Into Mainstream Education (M. J. Kaufman, M. I. Semmel, J. A. Agard)

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Abstract

The use of theory models for inquiry is first discussed. Evolution of systems models for educational research is then explicated. These include input⟶output, input⟶process⟶product, cybernetic (closed-loop/feedback), and general systems models (e.g., SIGGS). General systems models are preferable because they are inclusive of the others. SIGGS is further preferable because it is well defined. Project PRIME is concerned with evaluation of mainstreaming handicapped learners into regular classroom settings. One of the observation systems used in this evaluation is the Indiana Behavior Management System (IBMS), which is concerned with teacher management of off-task, deviant learner behavior. A theory of influence relations (reward, coercive, expert, legitimate referent, and informational) is utilized in characterizing teacher-learner relations derivable from IBMS. This theory is further framed through retroduction by the SIGGS model. It is then shown how influence relations would be characterized with information statistics in terms of proportionate reduction of uncertainty. Finally, the fruitfulness of this approach is discussed.

Introduction

Extant educational research has revealed little reliable, scientific knowledge of the teaching-learning process (Mood, 1970; Smith, 1971; Rosenshine, 1971; Soar, 1972; Rosenshine & Furst, 1973; Heath & Neilson, 1974; Dunkin & Biddle, 1974). It is patent, however, that teachers have come to know about education through observation of and participation in the teaching-learning process. It is also evident that such individuals may be skillful teachers, but may not be knowledgeable about education. That is, a teacher can be effective in producing student learning, yet not be able to explain why.

While it appears that scientific knowledge of the teaching-learning process lacks general predictive or explanatory power, it is not implied that philosophical knowledge of education is lacking (e.g., Dewey, 1916). Nor is it implied that praxiological knowledge of education is necessarily deficent (e.g., Montessori method). In short, there does not exist currently a well-defined valid body of quantitative knowledge which constitutes a science of education.

Perhaps our models for conceptualizing educational research are in need of modification.

The Use of Theory Models
in Research

The complete act of inquiry involves retroduction, deduction, and induction (e.g., see Pierce, 1958; E.S. Maccia, 1963; Dewey, 1916). The notion of retroduction was formally introduced by Pierce in the ninetheenth century, while deduction and induction are much older concepts.

Deduction is usually associated with rules of conceptualization. Formal logic is the basis of deriving specific hypotheses from more general theorems or postulates in deduction. Induction is just the converse--going from the specific to the general. Rules of induction are usually taken as rules for verification. These are commonly known as statistical rules of inference for comparing specific states of affairs (i.e., data) to hypotheses (e.g., see any textbook on statistical inference).

Retroduction is taken to mean the use of models <u>for</u> conceptualizing or theorizing. Retroduction is referred to as the "theory models approach" (E. S. Maccia, G. S. Maccia, & Jewett, 1963). In contradistinction, a <u>theory</u> is a model <u>of</u> reality. When one theory is used as a model to generate another theory, the former (Theory A) serves as a theory <u>model</u> (analogy) <u>for</u> the latter (Theory B). For example, quantum physics theory (A) can be used to generate an all-or-none learning theory (B). Retroduction is in contradistinction to reduction in that Theory B is not reducible to Theory A. Retroduction differs also from deduction in that Theory B is not completely deducible from Theory A. Rather, through retroduction Theory A becomes a model for some, but not all, of Theory B.

Thomas S. Kuhn, in the Structure of Scientific Revolutions (1970), demonstrates the power of paradigms (methodologies, meta-models) in influencing the nature of scientific inquiry throughout the history of science. Jacob Bronowski, in The Ascent of Man (1973), likewise emphasizes the power of models for conceptualizing problems in research. Both Bronowski and Kuhn use the example of Copernicus to demonstrate the gripping influence of older paradigms in preventing newer and more adequate paradigms from being adopted. Astronomers in the Ptolemaic (older) paradigm viewed the earth as the center of the revolving heavens, whereas the Copernican paradigm stipulated that the sun was the center of the solar system and the earth was one of several planets which revolved in orbits around the sun. According to Bronowski, the word, 'revolution,' took on its addition meaning (i.e., overthrowing) because of the revolutionary ideas of Copernicus. Unfortunately it is often the case that newer paradigms (even while more adequate) are usually not adopted by a field of scientific inquiry until the leading proponents of the older paradigms literally die off (e.g., see Kuhn, 1970).

In the field of human sciences an organismic paradigm is emerging to supplant a mechanistic view of human being (e.g., see C. W. Churchman, 1968; Ackoff & Emery, 1972; Miller, 1974;

Banathy, 1973; von Bertalanffy, 1968; E. S. & G. S. Maccia, 1976). The organismic view is not new. Some relatively recent manifestations of this view in education-related fields are found in the Gestalt view of psychology at the turn of this century, Dewey's philosophy of functionalism, and most recently, general systems theory.

Ludwig von Bertalanffy (1955, 1968) is given credit for first proposing a general systems theory. it is important to note the difference between general systems, specific systems, and mechanism: General systems is a holistic, or an organismic perspective. The whole is seen as determining relations among parts (components) which comprise a system. In a strictly mechanistic (atomistic) view, parts are viewed in isolation rather than in complex relation and are seen as additive, or summing to form a whole. In a general systems view the whole is said to be greater than the sum of its parts. In this perspective a system is also viewed in mutual or complementary relation to its surroundings, or environment. Not only can the environment influence the system but also the system can influence the environment.

General systems have properties on them over and above specific systems such as closed systems, nervous systems, air-conditioning systems, biological systems, ecological systems, and so on. Ludwig von Bertalanffy (1968) asserted that there are isomorphisms across many different disciplines or fields of inquiry (e.g., physics, anatomy, sociology).

That is, there are general properties of systems which are inclusive of all specific systems. He envisioned a unification of science through general systems theory. General systems theory could be used as a model (or paradigm) for investigation in all fields of science, especially in fields where the science is relatively undeveloped and theory is not well-defined. The isomorphisms in general systems theory could be used as models for theorizing in such an immature science.

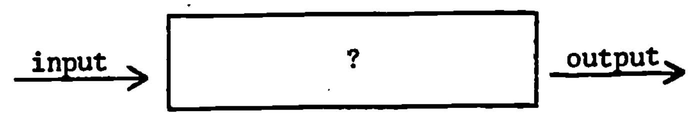
The science of education seems a likely candidate.

Evolution of Systems Models in Educational Research

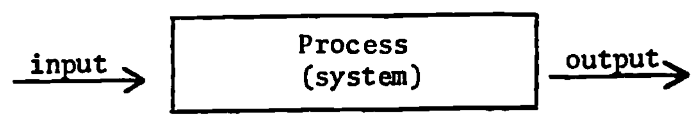
The use of the systems approach in educational inquiry is not new. A caveat is offered, however: the systems approaches used are often not in the spirit of general systems theory. Hence, we can easily become confused when we read studies which apply superficially the systems terminology, and yet, in actuality, are conceived and interpreted in a quite mechanistic (non-organismic) manner. The statistical models used in most extant educational research support a mechanistic view (i.e., linear, additive models, and assumptions of independence of observations).

Four types of systems models and exemplary educational research, if extant, will be discussed: input → output, input → process → product, cybernetic (closed-loop feedback), and general systems models. It will be seen that each model is successively inclusive of the previous one(s).

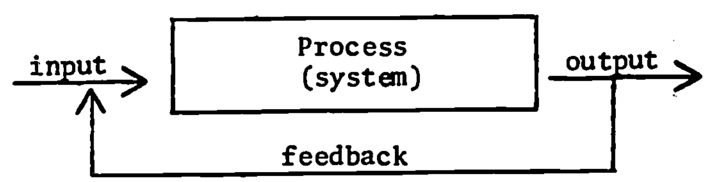
Schema 1.1. Input ⟶ Output Model



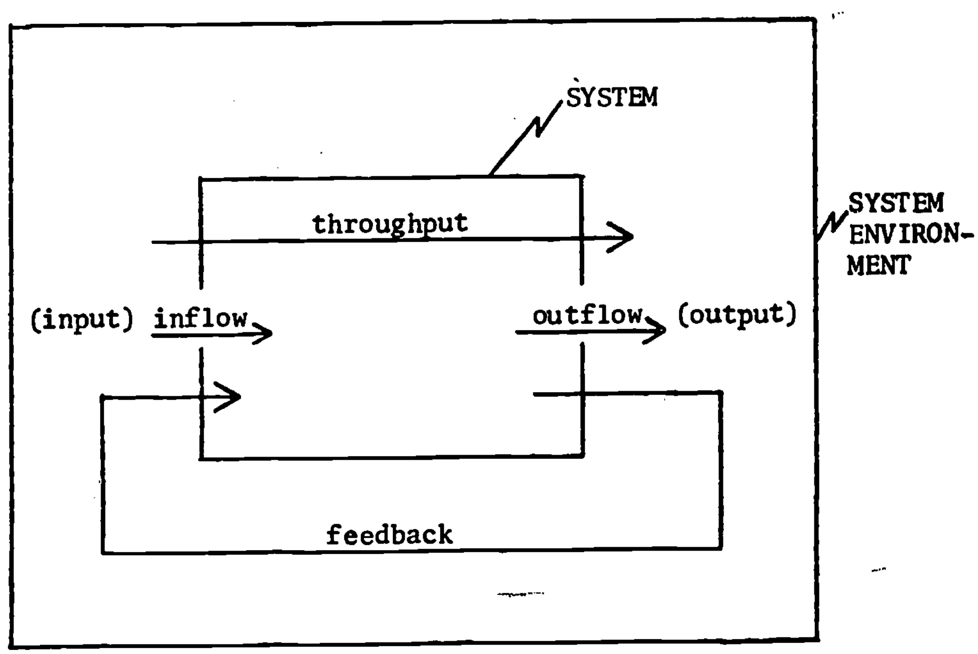
Schema 1.2. Input ⟶ Process ⟶ Output Model



Schema 1.3. Cybernetic (Feedback) Model



Schema 2. General Systems Model



Input $\rightarrow$ output model. In this model what comes out of a system (output) is viewed in terms of what goes into the system (input), with no direct concern as to what goes on within the system. The system is taken as a black box. See Schema 1.1. The Coleman report on Equality of Educational Opportunity (1966) exemplifies this input $\rightarrow$ output model. Input variables such as learner sex, socioeconomic status (SES), race, and teacher verbal ability were used to predict learner academic achievement as an output variable. Guthrie (1970) has also reviewed 18 other major studies in which various school inputs have been investigated in an attempt to predict learner academic achievement as the primary school output.

Input $\rightarrow$ process $\rightarrow$ output model. In educational research this model is sometimes termed, "Input $\rightarrow$ Process $\rightarrow$ Product" or "Presage $\rightarrow$ Process $\rightarrow$ Product" (e.g., see Semmel, 1974; Dunkin & Biddle, 1974). The black box (the system) is included in this model in characterizing the teaching-learning process. It can be seen (Schema 1.2.) that the input $\rightarrow$ output model is contained in the input $\rightarrow$ process $\rightarrow$ output model. Process characterizations are usually obtained through systematic observation of classrooms (e.g., see Simon & Boyer, 1974; Semmel, 1975; Flanders, 1970; Medley & Mitzel, 1963). In this model, input and/or process variables are used to predict output (product) variables. A recent example of application of this model was Project PRIME (Kaufman, Semmel & Agard, 1973). The major purpose of the study was to determine for whom and under what conditions mainstreaming of mildly handicapped pupils is a viable educational alternative. Some of the input variables were learner socioeconomic status, ethnic background, sex, and handicapping conditions. Process variables included classroom observation of pupil participation, learner on- and off-task behavior, teacher behavior management and questioning styles, and classroom climate measures. Examples of product variables were learner academic achievement, teacher ratings of pupils, learner social status in the classroom, and learner attitudes and feelings about school.

An assumption underlying these two models is that input and/or process variables influence output variables. What is usually neglected, however, is the simultaneous influence of output variables on input and/or process variables (Levin, 1970). For example, the influence of learner attitude on academic achievement is investigated without simultaneously accounting for the influence of academic achievement on attitude. What is lacking is a feedback relation.

<u>Cybernetic (closed-loop feedback) model</u>. This model is a further extension of the input ⟶ process ⟶ output model in that output can be viewed as regulating input. (See Schema 1.3). The system is said to be self-regulating, or cybernetic, or homeostatic (see Wiener, 1948; Cannon, 1932). In education, a clear example of utilization of this model is the Computer-Assisted Teacher Training System (CATTS) (Semmel, 1968; Semmel, Olson, & Weiske, 1972; Semmel & Frick, 1975). CATTS is an application of computer technology in assessing teacher/learner performance through systematic observation.

The technology allows immediate feedback of results of that performance in real time so that a teacher can regulate his/her teaching behavior in accordance with pre-established teaching objectives.

General systems models. The general systems model is a further extension of the cybernetic model (von Bertalanffy, 1968; Miller, 1974). See Schema 2. It can be seen that the system is viewed in interaction with its environment or surroundings. The environment can modify the system, as well as the system can affect the environment--hence, the addition of throughput (feedthrough, flowthrough) to the cybernetic model. Whereas in the cybernetic model output was viewed as directly affecting input (closed-loop feedback), in the general systems view feedback is seen as going through the environment and back to the system. That is, the environment can act on the system, as well as the system on the environment. There is complementarity or reciprocality between system and environment.

In an educational system these would be called transactional teacher-learner systems, if the teacher is the system of focus and the learner is the teacher's environment (G. S. & E. S. Maccia, 1975). The difference is subtle, but significant. A cybernetic model would view the teacher as the agent of influence, whereas the general systems model views the teacher and learner both as mutual agents of influence. Hence, we consider not only the effects of the teacher on the learner, but also the effects of the learner on the teacher. That is, we truly look at teacher-learner interaction. If the teacher is the system of focus (and the learner is part of the teacher's environment), the latter is feedthrough (environment ⟶ system ⟶ environment), and the former is feedback (system ⟶ environment ⟶ system).

There are few examples of utilization of general systems models in educational research. Beginnings of such research is found in works by Banathy (1973; 1975), E. S. & G. S. Maccia (1976, 1975, 1969, 1966), Semmel & Frick (1975), Ames (1975), and a few others. Applications of general systems models to research and/or development are more readily found outside education (e.g., von Bertalanffy, Rappoport, Mesarovic, Ashby, Churchman, Ackoff, Emery).

Mathematical Characterizations of Systems

Much of extant educational research has been organized under the mechanistic (atomistic) model. See Schemas 1.1, 1.2, and 1.3. Most statistical textbooks in the behavioral sciences start with assumptions for a linear, additive model (e.g., Hays, 1973, Kirk, 1968; Kerlinger & Pedhauzer, 1973). While good statisticians warn the researcher to not apply this linear, additive model to research data when such a model is not appropriate for characterizing types of relations suggested by the theory or questions of interest, we often forget or ignore this advice (e.g., see Kaplan, 1964; Combs, 1960).

In analysis of variance, or more generally, the structural equation approach (e.g., multiple regression, path, cannonical, factor, and discriminate analysis), deviations from the regression line or curve are viewed as errors of measurement and/or residual errors. If such a model is used, then it is implicit in the theory to be verified that if all measurement errors were eliminated, and if all confounding effects were controlled, then each data point in _n_-dimensional space would ideally fall on the line (curve) predicted by the equation. But many of us have forgotten that the mathematical function for a line is an _imposition_ on the data. Such an imposition of function is not necessary for characterizing a mathematical relation among two or more variables. _T_ measures in information theory make no such imposition, for example.

The _same_ data points, expressed in a Cartesian coordinate system, are given in Figures 1.1., 1.2., and 1.3. Notice the differences in imposition of functions. In the first figure, we speak of deviations of points (residual error) from an ideal, continuous function which is expressed as an equation for a straight line. But why impose a straight line? Why not a complex squiggly line as in Figure 1.2.? Why impose any function? Why not view the relation as the _uncertainty_ of the joint occurrence of discrete regions of variable X and Y?

No function is imposed in Figure 1.3. The relation of X and Y is expressed in terms of probabilities of the joint occurrences of one discrete region (category, interval) and another. Moreover, the theory of interest dictates what these categories are (i.e., the boundaries among categories). In order to do this, the categories of variable X must be mutually exclusive (i.e., discrete) and exhaustive of all possible occurrences of variable (classification) X--likewise for Y.

Figure 1.1. Residual Errors in an XY Plot from a Simple Linear Function

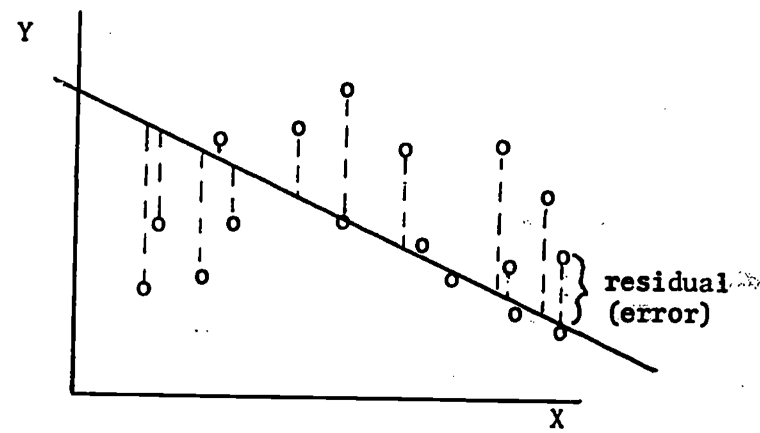


Figure 1.2. No Residual Errors by Using a Complex Linear Function to Characterize the Same Data as in Figure 1.1.

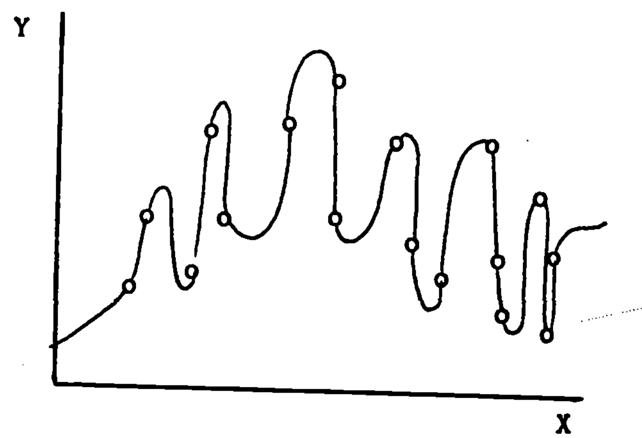
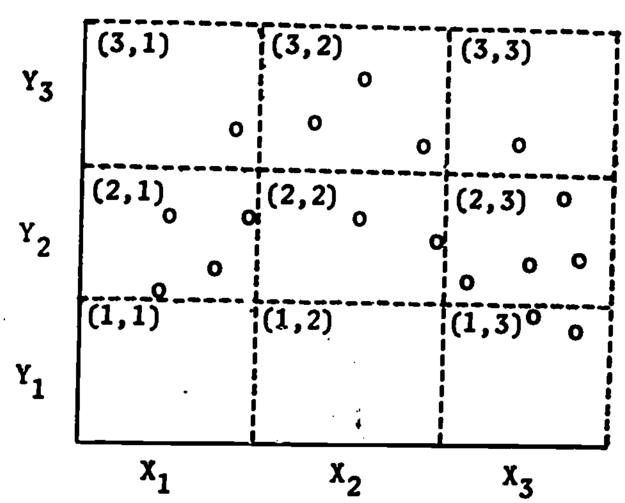


Figure 1.3. Characterization of Same Data as in Figure 1.1. in Terms of Uncertainty Using Mutually Exclusive and Exhaustive Categories (Intervals, Regions)



These assumptions are necessary to meet the basic tenets of probability theory and information theory. Notice, however, we have made no assumptions of linearity or additivity among variables. We are not imposing any mathematical equation (e.g., for a straight or curved line) from which deviations of data are considered as error of one type or another. We are simply characterizing the uncertainty of the relation <u>without</u> imposing any mathematical function.

The point of this discussion is to sensitize the reader that if we change our theory model (e.g., to a general systems model), then we must be careful of blindly applying traditional statistical procedures to new theories under the new paradigm. This is particularly true if it is believed that the linear, additive assumptions are unwarranted for complex organismic relations.

Further explication of information (uncertainty) statistics is given in a later section of this paper.

<u>Summary</u>

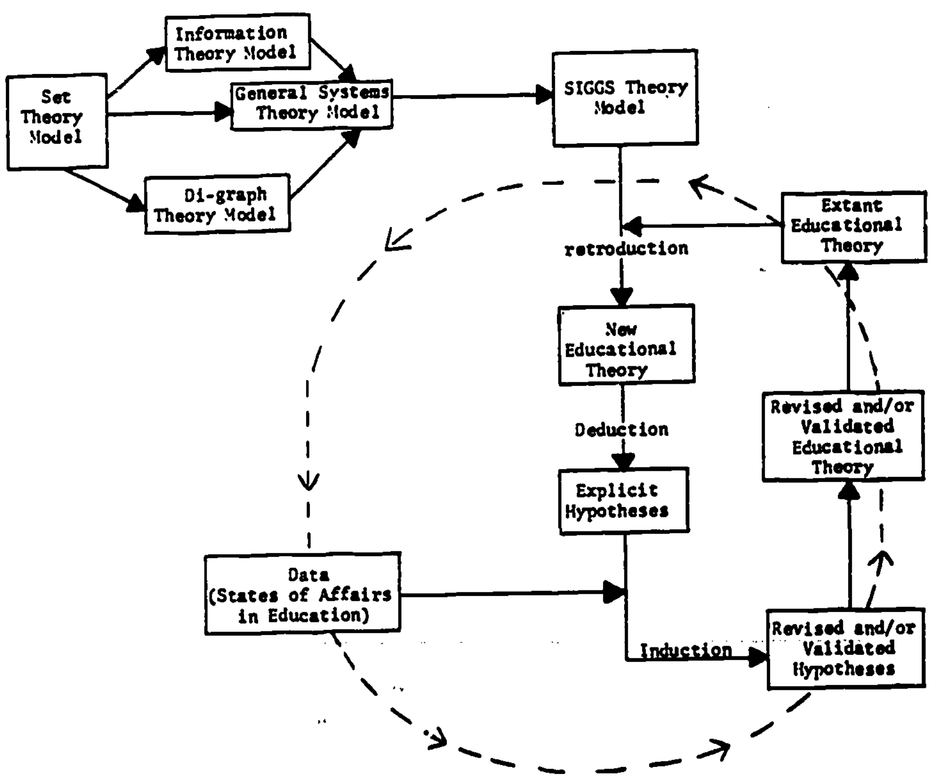
Varying degrees of utilization of systems models for conceptualizing educational research were discussed. It is apparent that general systems models are inclusive of input $\rightarrow$ output, input $\rightarrow$ process $\rightarrow$ product, and cybernetic (closed-loop feedback) models. It was emphasized that general systems is an organismic view in contradistinction to a mechanistic (atomistic) view. In the organismic view, the whole is taken to determine relations among the parts, and is, in a sense, greater than the sum of the parts. In addition, the system is viewed in mutual (complementary, transactional) relation to the system environment. It was then asserted that traditional statistical procedures may need modification (or reinterpretation) to characterize adequately complex relations among parts of systems, and system $\longleftrightarrow$ environment interactions.

Explication of the SIGGS Theory Model

The SIGGS theory model (E.S. Maccia & G.S. Maccia, 1966) is an extension of general systems theory. It was evident in the previous section that a general systems model was inclusive of specific (or limited) systems models. SIGGS is a further extension of general systems in that set theory, information theory, and di-graph theory are used as models to extend general systems theory. Set and digraph theory are mathematical theories, whereas information theory derives from communications engineering (e.g., Shannon & Weaver, 1949); and, of course, Ludwig von Bertalanffy (1955) is credited for general systems theory. The relationships among these four theory models, SIGGS, and educational inquiring is depicted in Schema 3.

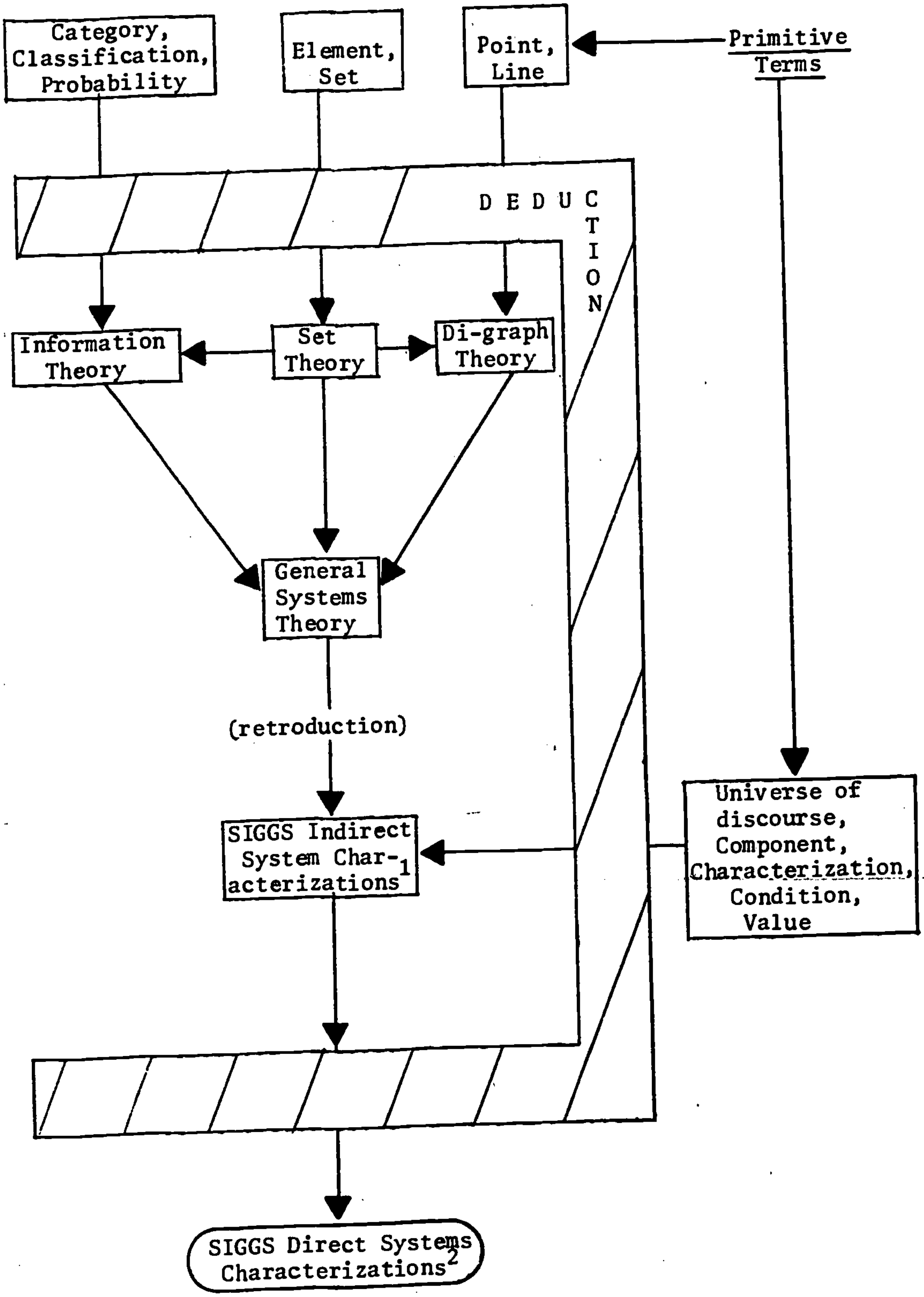
Schema 4 and Tables 2.1. and 2.2. illustrate the derivation of SIGGS from primitive terms. Primitive terms are necessary in any definitional system to prevent circularity. Given the primitive terms, 'universe of discourse,' 'component,' 'characterization,' 'condition,' and 'value,' indirect and direct SIGGS characterizations evolve in the order indicated by the numbers in Tables 2.1. and 2.2. Higher-order SIGGS characterizations are defined in terms of lower-order characterizations and ultimately in primitive terms. Whenever necessary, set-theoretic, information-theoretic, and graph-theoretic terms are employed, each of which is ultimately derived from its respective primitive terms. Thus, SIGGS meets the requirements of a formal definitional system.

Schema 3. Relationship of SIGGS to Other Theory*



*-------->-------- illustrates the inquiry process

Schema 4. Illustration of SIGGS Derivation



[1] See Table 2.1.
[2] See Table 2.2.

Table 2.1. SIGGS Indirect System Characterizations*

1. Group

2. Information

    2.1. Selective Information

        2.1.1. Non-conditional Selective Information
        2.1.2. Conditional Selective Information

3. Transmission of Selective Information

4. Affect Relation

    4.1. Directed Affect Relation

        4.1.1. Direct Directed Affect Relation
        4.1.2. Indirect Directed Affect Relation

6. Negasystem

8. Negasystem State

10. Negasystem Property

12. Negasystem Property State

14. Negasystem Environmentness**

16. Negasystem Environmental Changeness

19. Fromputness

20. Outputness

*Taken from Maccia & Maccia (1966), p. 68.
**14, 16, 19, and 20 are negasystem properties.

Table 2.2. SIGGS Direct System Characterizations*

Non-Properties

5. System
7. System State
9. System Property
11. System Property State

Properties

13. System Environmentness
15. System Environmental Changeness
17. Toputness
18. Inputness
19. Storeputness
20. Feedinness
21. Feedoutness
22. Feedthroughness
23. Feedbackness
24. Filtrationness
25. Spillageness
26. Regulationness
27. Compatibleness
28. Openness
29. Adaptiveness
30. Efficientness
31. Complete Connectionness
32. Strongness
33. Unilateralness
34. Weakness
35. Disconnectionness
36. Vulnerableness
37. Passive Dependentness
38. Active Dependentness
39. Independentness
40. Segragationness
41. Interdependentness
42. Wholeness
43. Integrationness
44. Hierarchically Orderness
45. Flexibleness
46. Homomorphismness
47. Isomorphismness
48. Automorphismness
49. Compactness
50. Centralness
51. Sizeness
52. Complexness
53. Selective Informationness
54. Size Growthness
55. Complexity Growthness
56. Selective Information Growthness
57. Size Degenerationness
58. Complexity Degenerationness
59. Selective Information Degenerationness
60. Stableness
61. State Steadiness
62. State Determinationness
63. Equifinalness
64. Homeostasisness
65. Stressness
66. Strainness

*Taken from Maccia and Maccia (1966), p. 69.

A system is defined in natural language as "a group of at least two components with at least one affect relation and with information" (Maccia & Maccia, 1966, p. 95). To illustrate the precision and clarity of the formal definition of a system the following is given (which is a read-off of the predicate calculi used for logical definition):

> ['System,' $\bar{S}$] equals by definition ['group, S, such that there is a family of affect relations, $\mathcal{R}_A$, such that $\mathcal{R}_A$ is not equal to the null set, $\emptyset$] [and for all affect relations, R_A, R_A is an element of $\mathcal{R}_A$, only if R_A is contained in the Cartesian product of S and S,] [and there is a family of informations, $\mathcal{I}$, such that $\mathcal{I}$ is not equal to $\emptyset$,] [and for all information, I, I is an element of $\mathcal{I}$ only if either (I is equivalent to R_A) (or there is a family of affect relations, $\mathcal{R}$, such that $\mathcal{R}$ is contained in the power set of R_A and I is equivalent to $\mathcal{R}$) (or there is a group, S´, such that S´ is contained in S and I is equivalent to S´ and I is not equivalent to any combination thereof')] (Maccia & Maccia, 1966, p. 45)[1].

Each of the terms used in the definition of a system was previously defined. The term, 'information,' was, for example,

---

[1]Brackets, [], and parentheses, (), were added to help organize the parts of the definition for the reader. Hereafter, only natural language definitions of terms will be given, since it is assumed that most readers will not understand the predicate calculi. It should be pointed out, however, that it is just those calculi which allowed such precise extension of general systems theory.

previously defined in natural language as a "characterization of occurrences" (Maccia & Maccia, 1966, p. 40). Ultimately, every term in the formal definition of a system can be traced to the set of primitive terms in Schema 4. Thus, it can be seen that SIGGS characterizations are given meaning from set-, information-, di-graph-, and general systems-theoretic characterizations. SIGGS characterizations are given further meaning in the teaching-learning process when used as a model for retroduction of new educational theory. (See Schema 3.)

The key terms in the definition of a system are 'group,' 'affect relation,' and 'information.' Each of these terms will be discussed briefly:

Group. The characterization, 'group', is akin to set in set theory in which the components of the group are like the elements of a set; and there are at least two components which comprise the group. Moreover, the group must be a subset of the universe of discourse. Universe of discourse, component, and characterization are primitive (undefined) terms. Boundaries of the system are defined by the set-theoretic characterization, 'complement'. That is, those components in the universe of discourse not taken to be in the group (which is the system) comprise the negasystem (literally, not-system)[2].

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[2]Do not confuse negasystem with 'system environmentness' which is 'toputness'. 'System environmentness' has conditions on it over and above those of the negasystem.

The group has conditions on it over and above that of a set of two or more components which form a unit in the universe of discourse. The group must have at least one affect relation which has information in order for the group to be a system.

Information. 'Information' is taken as a characterization of occurrences. Like elements which are members of a set, categories are members of a classification. Moreover, the categories must be mutually exclusive and exhaustive of the classification. That is, every occurrence of a system component can be characterized by one and only one category in a classification, and all component occurrences can be characterized by the classification. These conditions on the characterizations allow the assignment of a probability to each category in the classification, and the probabilities of all categories sum to unity.

The added condition of 'selectivity' to information means that there is uncertainty with respect to occurrences at the categories in a classification. Thus, at least one category has an associated probability of occurrence which is greater than zero and less than unity. Therefore, there must be at least one other category which also has a non-zero, non-unity probability of occurrence. In this sense selective information is synonomous with uncertainty of component occurrences.

Affect Relation. A system is defined as a group with at least one affect relation with information. The term, 'affect relation,' is defined as "a connection of one or more components to one or more other components" (Maccia & Maccia, 1966, p. 42). An affect relation is likened to mapping of the group onto itself in set theory--a Cartesian product of the group (set) onto itself, such that a component (element) cannot occur with itself in any given ordered pair of components. Digraph theory adds further meaning by the notion of directed lines connecting points in space. The directed lines indicate the channels between components and the sequence of connections among components (which are akin to points).

Information can be used to characterize component occurrences, or affect relations among components, or both. The added consideration of time of occurrence of components allows characterization of flow within and across system boundaries.

Availability. Finally, the consideration of availability of the negasystem to the system (or conversely) sets off those components in the negasystem which are available to the system from those which are not. Those negasystem components which are available to the system are defined as 'system environmentness'. Likewise, those system components which are available to the negasystem are defined as 'negasystem environmentness'. These considerations allow distinctions among toputness, inputness, fromputness, outputness, and storeputness. The additional consideration of time allows definition of flows within and across system boundaries (feedinness, feedoutness, feedbackness, feedthroughness). See Schema 5 and Tables 3.1. and 3.2.[3]

The reader will note that the information properties of a system (illustrated in Schema 5) are only but a few of the many system properties listed in Table 2.2. Thus, hypotheses about interrelationships among components of a system can be entertained and tested in the more comprehensive terms of system properties in Table 2.2. For example, not only can the function of shared information between presage (toputness) and product (outputness) variables be estimated across time (feedthroughness), but also dynamic constructs such as efficientness, stressness, integrationness, compatibleness, etc., can be entertained as well within hypotheses.

In short, extant theory about the teaching-learning process is extended when viewed in a SIGGS (extended general systems) framework. While only an introduction to SIGGS is intended here, already it can be seen how SIGGS adds clarity, precision, and completeness to extant conceptual models (paradigms) and/or theories in education (see Schemas 1.1, 1.2, 1.3, and 2 vs. 5). The further power and utility of SIGGS is demonstrated by framing one of the observation instruments (Indiana Behavior Management System - II, Fink & Semmel, 1971) used in Project PRIME in the context of a power (influence, leadership) theory set forth by French and Raven (1959).

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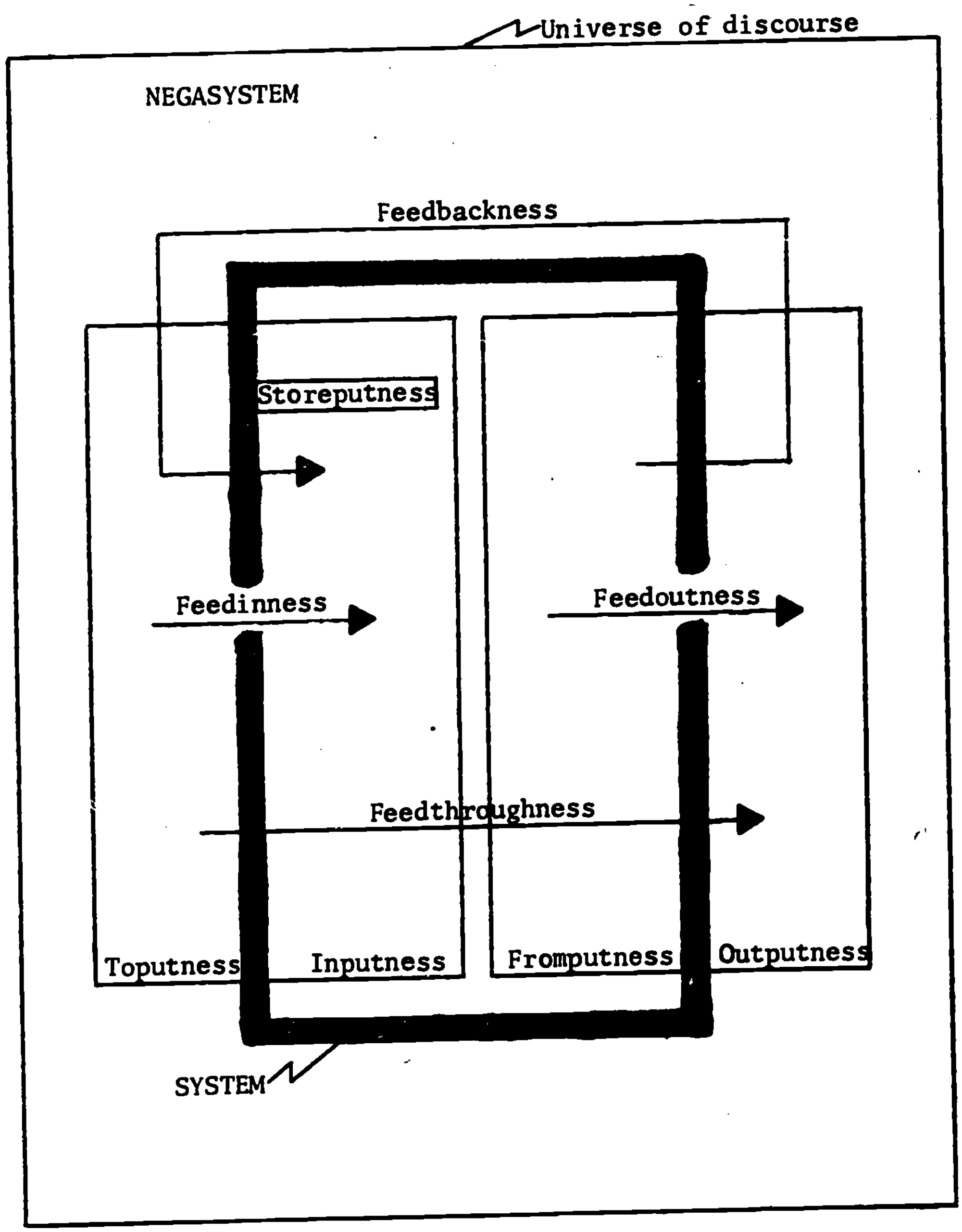
[3]The interested reader is referred to Coombs, et al. (1970), Maccia, Maccia, & Jewett (1963), and Atteneave (1959)

Schema 5. Information Properties of a System*



*Taken from Maccia & Maccia (1966), p. 99.

Table 3.1. Natural Language Definitions of Basic SIGGS System and Negasystem Characterizations.*

1. Universe of discourse (primitive)
2. Component (primitive)
3. Group: at least two components that form a unit (set) with the universe of discourse
4. Characterization (primitive)
5. Information: characterization of occurrences
6. Selective information: information which has alternatives
7. Transmission of selective information: a flow of selective information (in time)
8. Affect relation: a connection of one or more components to one or more other components
9. System: a group with at least one affect relation which has information
10. Negasystem: components not taken to be in the system (but in the universe of discourse)
11. System environmentness: a negasystem of at least two components, with at least one affect relation which has selective information
12. Negasystem environmentness: a system with selective information
13. Toputness: system environmentness
14. Inputness: a system with selective information
15. Fromputness: negasystem environmentness
16. Outputness: a negasystem with selective information
17. Storeputness: a system with inputness that is not fromputness (i.e., not available to negasystem)

*These natural language definitions are taken directly from Maccia & Maccia (1966, pp. 40-52). Note that these definitions are not as precise as the formal ones using predicate

Table 3.2. Natural Language Definitions of SIGGS System/ Negasystem Flows*

1. Feedinness: transmission of selective information from a negasystem to a system (between toputness and inputness when toputness occurs at a time just prior to inputness).*

2. Feedoutness: transmission of selective information from a system to a negasystem (between fromputness and outputness when fromputness occurs at a time just prior to outputness).*

3. Feedthroughness: transmission of selective information from a negasystem through a system to a negasystem (between toputness, inputness, fromputness, and outputness, respectively, when toputness occurs at a time just prior to inputness, inputness occurs prior to fromputness, and fromputness occurs prior to outputness).*

4. Feedbackness: transmission of selective information from a system through a negasystem to a system (between fromputness, outputness, toputness, and inputness, respectively, when fromputness occurs at a time just prior to outputness, outputness occurs prior to toputness, and toputness occurs prior to inputness).*

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*Note that 'feedinness' and 'feedoutness' are similar to ordinary notions of input and output. However, 'inputness' and 'outputness' take on special meaning here, and are not

Application of SIGGS
to Project PRIME

Project PRIME is a large scale descriptive-correlational study to evaluate mainstreaming of mildly handicapped children in regular classrooms in Texas (Kaufman, Semmel, & Agard, 1973). The major question addressed in the study, analysis of which is currently in progress,[4] is, "For whom and under what conditions is mainstreaming of mildly handicapped children a viable educational alternative?" Mainstreaming refers to integration of mildly handicapped children into regular classroom settings on at least a part-time basis--which is in contradistinction to the traditional administrative arrangement of placing handicapped children in completely self-contained (special education) classes. In Project PRIME, data were collected on more than 2200 selected educable mentally retarded (MR), learning disabled (LD), and normal contrast (NC) children, on over 12,000 of their classmates, and on approximately 1300 teachers in 650 special education, resource, and third-, fourth-, and fifth-grade regular classrooms located in 150 schools in 43 school districts throughout the state of Texas (see Kaufman, et al., 1973). A normal contrast child was a randomly selected regular classmate of a mainstreamed handicapped child. Data on each selected child were obtained from 28 different instruments, including standardized

[4]Several research teams are in the process of jointly preparing a book containing the results and conclusions of this study. Final manuscript is expected to be complete by November, 1976.

achievement tests, rating scales, observation systems, questionnaires, and sociometric, attitudinal, and self-concept scales. Sources of data included the selected child him/herself, his/her teacher(s) and peers, trained observers, principals, special education directors, and school superintendents.

A caveat is in order at this point. While this author is among those researchers currently analyzing the PRIME data, the following example (in which SIGGS is applied to one of the PRIME observation systems) does not necessarily reflect the intentions of the principal investigators (Kaufman, Semmel, & Agard) in terms of a data analysis strategy for the PRIME evaluation, nor does it necessarily represent their acceptance of this author's point of view. The following example represents a potentially fruitful and somewhat unique attempt to utilize the general systems paradigm for framing educational research questions, and a utilization of information theory for analytic procedures. The example is viewed not as a final product--rather only as an initial endeavor.

IBMS in Relation to a Theory of Power

The Indiana Behavior Management System - II (IBMS--Fink & Semmel, 1971) is a PRIME observation system designed for recording simultaneously at ten-second intervals learner on- or off-task behavior, and teacher task or management of off-task learner behavior. Learner off-task behavior is considered as socially deviant behavior, whereas on-task means that the learner is attending to the task expected of him/her by the teacher. Teacher on-task means that the teacher is teaching (attending to instructional tasks), and teacher control is taken as social management of off-task learner behavior. It is patent that the purpose of teacher social management is to bring the learner back to task or to socially acceptable behavior. (See Table 4.1).

Since the focus of IBMS is primarily on learner off-task and teacher control behavior, a theory of influence (power or leadership) is implicit. Six types of influence have been posited by French and Raven (1959):[5] reward, coercive, legitimate, expert, referent, and informational. In Table 4.1 it can be seen how the 13 IBMS teacher categories are grouped by the present author into the six influence categories. We will assume that these categories are mutually exclusive and exhaustive of the classification called teacher influence attempts. That is, every occurrence of a teacher attempting to influence a learner can be characterized by one and only one of the six influence categories. Moreover, the nine IBMS learner categories have been grouped (in Table 4.1) into three mutually exclusive and exhaustive categories used by Raven and Kruglanski (from Horney, 1945) to characterize the effect of the influence attempt. They are moving toward, moving away, and moving against (in this case, the teacher's expectations of appropriate learner task or social behavior and/or attitudes). A brief discussion of these categories of teacher influence attempts and influence effects on the learner follows.

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[5]Other sources (e.g., Raven, 1965, 1973; Raven & Kruglanski, 1970; Cartwright, 1965; Collins & Raven, 1969; E. S. Maccia, 1963; Safer, 1975) were utilized in part, but will not be directly

Table 4.1. IBMS Categories and Categories of Influence Attempts and Effects

IBMS Teacher Categories	Influence Attempt (IA_T)
1. Task	Expert (Ex)
2. Control (Management)	---
2.1. Redirection	Expert (Ex)
2.2. Positive Consequence	Reward (Rw)
2.3. Negative Consequence	Coercive (Co)
2.4. Punishment	Coercive (Co)
2.5. Criticism-Demeaning	Coercive (Co)
2.6. Demand	Legitimate (Lg)
2.7. Conditioned-Stimulus	Legitimate (Lg)
2.8. Value Law	Legitimate (Lg)
2.9. Empathic-Sympathetic	Referent (Rf)
2.10. Humor	Referent (Rf)
2.11. Interpretive	Informational (In)
2.12. Probing	Informational (In)

IBMS Learner Categories	Influence Effect (IE_L)
1. On-task	Movement toward (+)
2. Off-task	---
2.1. Self-involvement	Movement away (o)
2.2. Noise	Movement away (o)
2.3. Verbal Interaction	Movement away (o)
2.4. Physical Interaction	Movement away (o)
2.5. Verbal Aggression	Movement against (-)
2.6. Physical Aggression	Movement against (-)
2.7. Verbal Resistance	Movement against (-)
2.8. Physical Resistance	Movement against (-)

Teacher reward power. The teacher attempts to influence the learner by the use of rewards (e.g., praise, tokens, good grades, prizes, extra privileges). The only IBMS category of this type is 'positive consequences,' in which the teacher promises the learner that something desirable (valuable) to the learner will happen as a consequence of the learner's actions in the appropriate direction.

Teacher coercive power. The teacher attempts to influence the learner by coercion (e.g., punishment, threats, physical force). Three IBMS categories are of this type: negative consequences, punishment, and criticism-demeaning. 'Negative consequences' are threats of consequences undesirable to the learner, if s/he does not act appropriately. 'Punishment' and 'criticism-demeaning' mean what their names describe.

Teacher legitimate power. The teacher attempts to influence the learner on the basis of the teacher's role or socially defined authority (e.g., "Because I am the teacher I have a right to tell you what to do."). Three IBMS categories are of this type: demand, conditioned-stimulus, and value-law. Teacher 'demand' is a verbal command to the learner to cease his/her off-task behavior and/or return to task. Teacher 'conditioned-stimulus' is a signal or cue which has the implicit meaning of a demand (e.g., "shh," "Hey!", clears throat, stares menacingly). Teacher 'value-law' is an appeal to an established classroom norm of action (e.g., "You know that you must ask for permission to talk to your friend.").

Teacher expert power. The teacher attempts to influence the learner on the basis of authoritativeness (not authoritarian influence)--on the basis of the teacher's superiority of knowledge or skill. Two IBMS categories seem to fit this type of influence: teacher task and redirection. Teacher 'task' means that the teacher continues to engage in the tasks of instruction. If the learner is misbehaving, the teacher makes no reference to the learner's misbehavior; and teacher task in this situation could be construed as intentional ignoring, if the teacher was aware of the deviance. Teacher 'redirection' is moving the learner to an appropriate task without reference to the misbehavior (e.g., Johnny has been teasing Sally and the teacher says, "Johnny, come up here and help me pass out these papers.")

Teacher referent power. The teacher attempts to influence the learner on the basis of the learner's identification with the teacher (e.g., the learner acts appropriately because s/he likes the teacher as a friend, or because s/he respects the teacher as a person). Two IBMS categories seem to be of this type: empathic-sympathetic and humor.

Teacher informational power. The teacher attempts to influence the learner on the basis of validity or truth of knowledge (e.g., "You should not smoke in class because it is dangerous to your health as well as ours. Medical research has shown a correlation between smoking and lung cancer and other respiratory diseases.") Two IBMS categories seem to characterize this type of influence: teacher interpretive and probing. The former is a giving of reasons for learner misbehavior (e.g., "You're sulking because no one chose you on their team."); whereas the latter is an asking for reasons for learner misbehavior (e.g., "Why did you hit Sam?").

While French and Raven (1959) intended these categories of influence[6] to characterize the influence relations of the influencee and the agent of influence, it seems reasonable to use them to characterize the attempts of the agent of influence. Of course, the purpose of influence is to bring about a change in the influencee according to the agent's objectives. Not always will the attempt succeed, and therefore it is informative to characterize the effects of the influence attempt. They can be characterized by moving toward, away, and against.

Learner effect of moving toward. The effect on the learner is that the learner acts (or believes) in accordance with the agent's (teacher's) objectives. The IBMS category, learner on-task, is just this effect.

Learner effect of moving away. The effect on the learner is that the learner does not change in the desired direction as a consequence of the influence attempt, but the learner does not oppose or resist the influence attempt. Previous or current learner acts of beliefs persist, which are not in accordance with the teacher's objectives. Four IBMS learner off-task categories seem to fit this type of effect: learner self-involvement, noise, verbal interaction and physical interaction. These are learner behaviors which are neither on-task

[6]The sixth category, information, was considered as a type

nor overtly aggressive/resistive of teacher controls.

Learner effect of moving against. The effect of the teacher influence attempt on the learner is one of the learner's definite opposition to the teacher. Four IBMS learner off-task categories seem to fit this type: learner verbal aggression, physical aggression, verbal resistance, and physical resistance.

Now that influence attempts and influence effects have been described, one might hypothesize (as Raven has done) the kinds of effects that would result from each type of influence. Raven has viewed the effects in a four-fold manner. For each type of influence, the effect on the influencee can be characterized by the nature of the social interaction with the agent of influence, the nature of identification with the agent, the opinion of or belief in the task expected by the agent, and the actual task engagement or task behavior. For example, the teacher might scold the learner (coercive influence attempt) which might result in appropriate task behavior (+ behavior effect), but also might result in feelings of hostility towards the teacher (- identification), social interaction which was unfriendly (- social interaction), and dislike of or disbelief in the task expected (- opinion/belief).

It is clear that in the IBMS only one of the four-fold effects posited by Raven can be characterized--task behavior (+,∅,-). In Project PRIME many other measures of the learner were collected, in addition to the IBMS, which would characterize some of these other effects suggested by Raven. For purposes of illustration here, we will only be concerned with the IBMS in exemplifying some of SIGGS information properties.

SIGGS Framing of Influence Relations

Mainstreaming of mildly handicapped learners into regular classroom settings came about as a result of growing concern over the long-range deleterious effects of educational labeling and segregation of handicapped children in self-contained special classes. Mainstreaming was also given further impetus by court litigation emphasizing unjust discrimination against minorities and lower socioeconomic classes in labeling and placement in special classes (see Kaufman, et al., 1973).

The reader is reminded that special education came about early in this century in order to give special instruction to those students who were not able to successfully adapt to the modes of instruction in the regular classroom. A dilemma is evident. If the child who previously could not function acceptably in a regular class, and was placed in a special class, is now brought back to the regular class, why should we expect him/her now to function acceptably? The issue is complex. This is why the question is addressed in Project PRIME--for whom and under what conditions is mainstreaming of mildly handicapped children a viable educational alternative? Is mainstreaming viable only in non-academic subjects? Only for females? Only for MR's in regular classrooms which are of similar ethnic and SES composition? Only in regular classes in which the teacher favors mainstreaming? Only in classes where the regular classmates socially accept the handicapped child? Only in third-grade, but not fourth and fifth-grade?

The word, 'viable', is significant here, because we must ask: viable for whom--the handicapped child, the regular classroom teacher, regular classroom peers, or the school principal? We must ask further: What are the indicators of viability? For the handicapped learner who is mainstreamed, some of the indicators might be:

- feels secure, comfortable, accepted in the regular class,
- desires to learn in the regular class,
- is able to learn in the regular class,
- is able to get along socially with the regular classroom teacher and peers.

For the regular classroom teacher who is to instruct the mainstreamed learner, some of the indicators might be:

- is comfortable with, accepts the handicapped learner,
- desires to teach the handicapped learner,
- interacts with and gives handicapped child individual attention like any other student,
- plans classroom activities which include the handicapped learner.

In this illustration, we will initially focus on the influence attempts of the teacher, and the influence effects on the learner. If the learner is moving toward (+) the task expected by the teacher, this would indicate that the learner is probably attempting to learn, which would be _a_ desirable outcome of mainstreaming. If the learner is moving away (Ø) or moving against (-) the learning task expected by the teacher, this would indicate that the learner is probably not attempting to learn or overtly opposing the learning task or teacher.

Let us take the regular classroom as the universe of discourse, and the mainstreamed handicapped learner as the system of focus in SIGGS. (See Schema 5.) The learner's negasystem would include the teacher, peers, books, chairs, etc. When the teacher attempts to influence the learner, the teacher is learner toputness in SIGGS. That is, the teacher becomes information which is available to the learner system. When subsequently taken in by the learner system, toputness is said to affect inputness. Learner inputness is then, here, the effect of the teacher influence on the learner system. This relation is feedinness, or the sharing of information between toputness and inputness, when toputness occurs just prior to inputness. We can characterize the uncertainty of this feedinness relation by information statistics.

Information Statistics

In Table 5 the joint classification of learner toputness (T) and inputness (I) is illustrated. Note that the requirements of information theory have been satisfied here. Each and every occurrence of a teacher influence can be characterized by one and only one category (component) of the classification of influence attempts (IA_T). Likewise, these information requirements are satisfied by the components of the classification on the learner system (IE_L). If these requirements were not met we could not legitimately use information (uncertainty) statistics to describe the joint classification. Feedinness characterizes the flow from toputness (information in the negasystem which is available to the system) to inputness (which is a system with selective information). That is, how are changes in teacher influence attempts related to changes in learner task behavior? We can characterize the uncertainty of this affect relation by a $\underline{T}$ statistic. $\underline{T}$ is comprised of $\underline{H}$ statistics. The $\underline{H}$ statistic is the basic information or uncertainty statistic.

$\underline{H}$ is used to describe the average uncertainty of occurrences of categories in a classification.[6] $\underline{H}$ is a non-metric statistic, because there is no metric in a nominal classification. Analogously, variance (σ^2) is a metric statistic used to indicate average dispersion of interval measures around the center of the distribution, which is the mean, $\overline{X}$.

When $\underline{H}$ is zero, there is zero uncertainty, or total certainty. When $\underline{H}$ is greater than zero, there is some uncertainty. $\underline{H}$ can never be less than zero. The formula for $\underline{H}$ is given:

$$(1) \qquad \underline{H}(\underline{C}) = -\sum_{i=1}^{n} [p(\underline{c}_i) \times \log_2 p(\underline{c}_i)].$$

This formula is read: the average uncertainty, $\underline{H}$, of an occurrence of any category in the classification, $\underline{C}$, is equal to the negative sum of the $\underline{n}$ respective products of the probability of each category, $p(\underline{c}_i)$, and the logarithm to the base two of its probability, $\log_2 p(\underline{c}_i)$. (This results in a positive value of $\underline{H}$ because the logarithm of a fraction is negative.)

---

[6]See Coombs, et al. (1970) and Atteneave (1959) for a more detailed discussion of information statistics.

Table 5. Characterization of the Feedinness Relation Between Learner Toputness Which Is Teacher Influence Attempt and Learner Inputness Which Is Influence Effect*

		Consequent Learner Inputness ($I=IE_L$) +	∅	-	
Antecedent Learner Toputness ($T=IA_T$)	Reward (Re)	94	283	59	436
	Coercive (Co)	5	22	0	27
	Legitimate (Lg)	132	69	12	213
	Expert (Ex)	479	437	18	934
	Referent (Rf)	82	0	0	82
	Informational (In)	119	0	73	192
		911	811	162	1884

$$\underline{H}(I) = - \left[\left(\frac{911}{1884} \text{ X } \log_2 \frac{911}{1884} \right) + \left(\frac{811}{1884} \text{ X } \log_2 \frac{811}{1884} \right) + \left(\frac{162}{1884} \text{ X } \log_2 \frac{162}{1884} \right) \right] = 1.335$$

$\underline{H}(T) = 1.967$ $\qquad\qquad$ $\underline{H}(TI) = 3.056$

Feedinness $= \underline{T}(T,I) = 1.335 + 1.967 - 3.056 = .246$

$\underline{rT} = [\underline{T}(T,I)/\underline{H}(I)] \text{ X } 100$

$= (.246/1.335) \text{ X } 100 = 18\%$ reduction uncertainty

---

*These are fictitious data for purposes of illustration only. '+' is moving toward; '∅' is moving away; and '-' is moving against.

Table 6. Characterization of $L_i \longrightarrow L_f$ Affect Relations*

Consequent Learner Fromputness ($F=IA_L$)

Antecedent Learner Inputness ($I=IE_L$)	+	ø	-	
+	X	855	56	911
ø	733	X	78	811
-	100	62	X	162
	833	917	134	1884

$\underline{H}(I) = 1.335$
$\underline{H}(F) = 1.297$
$\underline{H}(IF) = 1.775$

<u>System Flow</u> = $\underline{T}(I,F) = 1.335 + 1.297 - 1.775 = .857$

$\underline{rT}(I,F) = (.857/1.335) \times 100 =$ 64% reduction of uncertainty

*Again these are fictitious data.

Table 7. Characterization of the Feedoutness Relation Between Learner Fromputness Which Is Learner Influence Attempt and Learner Outputness Which Is Teacher Influence Effect*

Antecedent Learner Fromputness ($F=IA_L$)	Consequent Learner Outputness ($O=IE_T$): Re	Co	Lg	Ex	Rf	In	
+	81	0	0	752	0	0	833
Ø	12	0	127	571	125	82	917
-	2	47	85	0	0	0	134
	95	47	212	1323	125	82	1884

$H(F) = 1.297$
$\underline{H}(O) = 1.519$
$\underline{H}(FO) = 2.356$

<u>Feedoutness</u> = $\underline{T}(F,O) = 1.297 + 1.519 - 2.356 = .46$

$\underline{rT}(F,O) = (.46/1.297) \times 100 = 35\%$ reduction of uncertainty

*Again these are fictitious data for illustration only.

Suppose we characterize the uncertainty of 1884 occurrences of learner behavior. For example, if the learner was 'moving toward' we would make a tally in the '+' cell of the below table.

	+	∅	-	
frequencies	911	811	162	Total = 1884

When we finished counting up the tallies we observe that the learner was moving toward (+) 911 times, moving away (∅) 811 times, and moving against (-) 162 times. Given these data, at any given time the learner is most likely to be moving toward, slightly less likely to be moving away, and not very likely to be moving against. We can mathematically characterize this uncertainty by calculating an H for this distribution of learner inputness (I):

$$H(I) = -\left[\left(\frac{911}{1884} \times \log_2 \frac{911}{1884}\right) + \left(\frac{811}{1884} \times \log_2 \frac{811}{1884}\right) + \left(\frac{162}{1884} \times \log_2 \frac{162}{1884}\right)\right]$$

$$= 1.335$$

What does this H = 1.335 mean? There is obviously some uncertainty. If there were no uncertainty, H = 0. But it is helpful to know what the maximum uncertainty would be if each of the three categories were equally likely (i.e., same frequency in each cell). Maximum uncertainty, Hmax, is defined:

$$(2)\quad H_{max} = \log_2 n$$

where, n = number of categories in the classification.

For two categories, $Hmax = 1$; for eight, $Hmax = 3$; for four, $Hmax = 2$. For the three categories we have, $Hmax = 1.585$. Our $H(I) = 1.335$, which is closer to $Hmax$ than it is to zero. More specifically, we can calculate relative uncertainty, rH, by the below formula:

$$(3)\quad rH(C) = \left[\frac{Hmax - H(C)}{Hmax}\right] \times 100$$

$$\text{or}\quad rH(C) = \left[\left(1 - \frac{H(C)}{Hmax}\right)\right] \times 100$$

Therefore, in our example,

$$rH(I) = \left[1 - \left(\frac{1.335}{1.585}\right)\right] \times 100 = 15.8\% \text{ reduction of uncertainty.}$$

We can say that knowledge of the given distribution of 1884 occurrences of learner behavior reduces (from maximum) the uncertainty with which we could predict which inputness category is occurring (or might occur next) by approximately 16 percent.

We can calculate H for joint or multiple classifications. In general,

$$(4)\quad H\left(C_{IJK\ldots}\right) = \sum_{i}\sum_{j}\sum_{k}\ldots\, p\left(c_{ijk\ldots}\right) \times \log_2 p\left(c_{ijk\ldots}\right).$$

In Table 5 the uncertainty of the joint classification of toputness and inputness is calculated: $H(TI) = 3.056$.

Now we have all the formulas we need to calculate the T statistic for the relation between two or more classifications: the formula for T for two classifications is defined:

$$(5)\quad T(C_I, C_J) = (H(C_I) + H(C_J) - H(C_{IJ}).$$

In Table 5 it can be seen that $\underline{T}$(T,I), or feedinness, is .246. $\underline{T}$ is somewhat like a correlation coefficient, except that $\underline{T}$ can vary from zero upwards. When $\underline{T}$ is zero there is no relation; when $\underline{T}$ is greater than zero there is some relation, or some sharing of information between two classifications (here, between toputness, T, and inputness, I).

We can also calculate a relative $\underline{T}$, just as we estimated a relative $\underline{H}$. Relative transmission is defined:

$$(6)\quad \underline{rT}\left(\underline{C}_I, \underline{C}_J\right) = \left[\underline{T}\left(\underline{C}_I, \underline{C}_J\right) / \left(\underline{H}\left(\underline{C}_J\right)\right)\right] \times 100.$$

Relative transmission is akin to the $\underline{r}^2$ interpretation in metric statistics. We say that if $\underline{r} = .8$, then $\underline{r}^2 = .64$, or 64% of the variance in one interval level variable is explainable by the other interval variable. Relative transmission, $\underline{rT}$, which is non-metric, is akin to eta-squared (correlation ratio, squared) in standard analysis of variance interpretation. (See Costner, 1965, and Schmitt, 1969.)

In our fictitious example in Table 5, relative transmission is (.246/1.335) X 100, or an 18 percent reduction of uncertainty in learner inputness given knowledge of toputness. We would conclude here that there is little commonality between antecedent teacher influence attempts and consequent learner influence effects. That is, regardless of which type of influence the teacher chooses, there is little change in <u>the relative pattern</u> of learner behavior.

<u>Fruitfulness of SIGGS</u>

The reader might feel at this point that, other than application of information statistics, there is not much difference between a SIGGS framing of teacher $\longrightarrow$ learner influence relations and a more traditional framing (see Schemas 1.1. and 1.2.). The point of the simple example in Table 5 was to illustrate the basic information statistics, $\underline{H}$ and $\underline{T}$. There are many other properties of SIGGS besides feedinness, however. A few of these other properties will be touched upon here to illustrate how SIGGS can extend extant models.

In Table 7, the influence of the learner on the teacher is mapped. Feedoutness is flow from fromputness to outputness. Here antecedent learner behavior is viewed as an influence attempt by the learner (IA_L) and the consequent teacher behavior is viewed as the effect of the learner influence on the teacher (IE_T). Feedoutness, or transmission from the learner to the teacher, is .461. Compare this with feedinness of .246. The learner influences the teacher more than the teacher influences the learner in this fictitious example. Relative feedoutness yields a 35 percent reduction of uncertainty. That is, knowledge of antecedent learner influence attempt (here characterized by +, ∅, -) reduces the uncertainty of consequent teacher effect by about twice as much as the converse (35% vs. 18%).

Feedthroughness can show us the flow in time from the teacher (toputness) through the learner (inputness, fromputness) and to the teacher (outputness). Feedthroughness is defined mathematically as a multivariate $\underline{T}$ of order four:

$$(7)\quad \underline{T}(T, I, F, O) = \underline{H}(T) + \underline{H}(I) + \underline{H}(F) + \underline{H}(O) - \underline{H}(TI) - \underline{H}(TF) - \underline{H}(TO) - \underline{H}(IF) - \underline{H}(IO) - \underline{H}(FO) + \underline{H}(TIF) + \underline{H}(TIO) + \underline{H}(TFO) + \underline{H}(IFO) - \underline{H}(TIFO).$$

It can be seen that we need for feedthroughness the joint classification of toputness (T), inputness (I), fromputness (F), and outputness (O), where T is at t_1, I at t_2, F at t_3, and O at t_4; and t_1, t_2, t_3, t_4 are successive moments in time. Joint classification with more than two classifications is difficult to illustrate in a table, but the reader can get a feeling of this flow by looking successively at Tables 5, 6, and 7.

Probably more interesting than feedthroughness (teacher$\longrightarrow$ learner$\longrightarrow$teacher) is compatibleness (see Table 2.2, #27). Compatibleness is commonality of feedinness and feedoutness, and can be estimated by the $\underline{B}$ function, which is comprised of $\overline{\underline{T}}$'s. (See Maccia and Maccia, 1966, pp. 20-23; the formula for $\underline{B}$ is not given here to save space, since the $\underline{B}$ for compatibleness consists of 9 $\overline{\underline{T}}$'s, which in turn consist of 27 $\underline{H}$'s.) Intuitively, compatibleness characterizes the relation between what is taken in by a system from its environment, and what is subsequently taken in by the negasystem from the system. If there is little compatibleness between a teacher and mainstreamed learner, one might expect strainness in the learner and/or stressness in the teacher to increase (see Table 2.2., #65 and #66). If strainness in the learner increases beyond a certain level, we might then expect his/her anxiety level to increase, which might in turn lead to hostile or aggressive interaction with the teacher and/or peers. This antagonism might foster social rejection by peers and teacher negative feelings toward the mainstreamed handicapped learner. This could lead to exclusion of the handicapped child from regular classroom activities. The handicapped child would be, in effect, isolated from the regular classroom, although physically present. That is, there would be disconnectionness in the classroom system (see Table 2.2., #35).

Such a situation would not be a viable outcome of mainstreaming in this author's opinion.

Concluding Remarks

Only a few of the SIGGS properties were considered in discussing the potential fruitfulness of SIGGS in extending research questions in Project PRIME. Adaptiveness (#29 in Table 2.2) was not considered, for example. "Adaptiveness is a difference in compatibleness under system environmental changeness" (Maccia & Maccia, 1966, p. 53). Adaptiveness of the mainstreamed handicapped learner to the regular classroom might very well be one of the most important considerations in mainstreaming.

Also, it should be noted that, in the previous example, components in the learner system and teacher system were rather crude and simplistic. Learners consist of more than just task behavior of moving toward, away, and against.

Learners have feelings, intentions, and knowledge as well. These could be characterized by storeputness in SIGGS, for example.

Moreover, the categories of teacher influence were not the same as those for the learner. These teacher/learner categories were probably devised originally in a mechanistic framework (i.e., only in terms of the teacher influencing the learner, but not the converse). In an organismic framework it is obvious that the learner can influence the teacher as well. That is, in SIGGS, there is feedoutness in addition to feedinness. Therefore, we should be using the same categories for the learner as for the teacher (because the influence is mutual). It was not feasible to have the same categories for each, obviously, in the example with Project PRIME, because it was originally conceptualized as an Input ⟶ Process ⟶ Output study.

In addition, the learner negasystem consists of more than just the teacher. There are curriculum and setting components, which can influence, as well as be influenced by, the learner system. These can easily be handled in SIGGS by the multivariate information statistics.

As was stated earlier, this paper is considered only as a beginning. It should be clear to the reader at this point, however, that the extended general systems model (SIGGS) can be a powerful and fruitful heuristic for researching education. It is hoped that further application of this model will contribute significantly to a science of education.

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Errata

1. Page 1, lines 16 and 17: 'deficient', not 'deficent'.
2. Page 2, line 6: 'nineteenth', not 'ninetheenth'.
3. Page 4, line 8: 'It', not 'it'.
4. Page 7, line 22: 'Semmel, 1974', not 'Semmel, 1975'.
5. Page 10, line 22: 'Coombs, 1960', not 'Combs, 1960'.
6. Page 42, line 19: '(.46/1.519) X 100 = 30', not '(.46/1.297) X 100 = 35'.
7. Page 44, line 23: ')).', not ').'.
8. Page 46, line 18: '30 percent', not '35 percent';
   line 21: 'one and a half times', not 'twice';
   line 22: '30', not '35'.