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ABSTRACT

Can the laws of learning be applied in the classroom? The issue is whether control over the stimulus affords management-control over the learning processes within the student. The S-R (stimulus-response) position in psychology, most notably associated with Skinner, tends to accept and assert the affirmative. However, accumulated experience with programed instruction leaves some doubt that effective and efficient instructional strategies can be derived solely from behavioral psychology. As an alternative basis for deriving meaningful instructional strategies, cybernetics has much to recommend it. The principles of iterative feedback control and regulation in the instructional process are discussed in this paper. The use of these principles in recent instructional theories is briefly illustrated. (Author)

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Psychology and/or Cybernetics as Basis for Instructional Strategy

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16. Abstracts

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Prefatory Note

This paper was presented at the American Educational Research Association annual meeting in Minneapolis, Minnesota, in March 1970, by Dr. Kopstein, Senior Staff Scientist at the Human Resources Research Organization, Division No. 1 (System Operations), Alexandria, Virginia. Dr. Seidel is Program Director for Work Unit IMPACT, Prototypes of Computerized Training for Army Personnel; research for the paper was done under this Work Unit.

PSYCHOLOGY AND/OR CYBERNETICS AS BASIS FOR INSTRUCTIONAL STRATEGY

Felix F. Kopstein and Robert J. Seidel

The issue to which this paper is addressed unquestionably merits the careful and continued consideration of persons engaged in defining the principles and improving the practice of effective instruction. Our purpose is to state the issue rather than to debate it, as it is not possible to consider this complex topic in a brief space. Clearly, the logical disjunction in the title is of the inclusive type, that is, possibly in the sense of "a combination of both."

For psychology, the question is "Can the laws of learning be applied in the classroom?" This was the title of a landmark symposium held in May 1958 and published in *Harvard Educational Review* in 1959. It produced essentially negative answers on the part of two distinguished participants with long careers in learning theory and research—Kenneth Spence and Benton Underwood. The third participant, Arthur Melton, took a more positive view, or, more accurately, implied that the pessimistic view was unthinkable. He said "... education is to psychology and the social sciences as engineering is to the physical sciences and as medical practice—especially preventive medicine—is to the biological sciences" (Melton, 1959, p. 97). Clearly, this view makes it not permissible to view psychology as irrelevant to education. Melton also said:

> "... the problem of learning—its nature and conditions—is so fundamental to the whole of psychological science that there is frequent, and understandable, confusion between the terms 'learning theory' and 'behavior theory.' On the other hand, the technology of educational methods—if one means by this, as I do, all methods of management of the learning processes of others in order to achieve certain prescribed behaviors or behavior capabilities—is the fundamental technical question in education." (p. 96)

It can be said with considerable justification that the well-known work of Pressey, of Crowder, of Skinner, and of many others in the technology of educational methods known as programed instruction, and that of C.R. Carpenter and A.A. Lumsdaine and associates in instructional film, and also that of J.H. Kanner in instructional TV, belies the pessimism of Spence ("The truth of the matter is that we psychologists have been asked to solve practical problems before we had the laws of behavior necessary to do so." 1959, p. 87). On the other hand, it is certain that, with one exception, the above-named workers have been sufficiently eclectic to leave as a moot point the true underpinnings in "learning theory" or in "behavior theory." The one exception is Skinner and his followers who, though avowedly atheoretical, rigidly follow an operationally-defined concept structure known as "operant conditioning."

In summary, operant conditioning involves the contingent reinforcement or reward of responses spontaneously emitted by an organism in such a way as to shape its behavior into some desired form. The organism can be human and the behavior can be verbal as in most formal instruction. We need not go into an in-depth review of the familiar principles of operant conditioning and their application (see, e.g., Skinner, 1957). It may be something of an oversimplification, but nonetheless basically correct, to say that followers of Skinner view the learning organism as coming under the control of the reinforcing agent operating in the environment (normally an experimenter or an instructor) by virtue of the agent's management of the reinforcement contingencies. In principle, according to the Skinnerian view, it is possible to achieve total control over the learning organism's behavioral forms in stepwise, cumulative fashion through the application of various schedules of reinforcement. These views are reflected in Skinnerian principles of programed instruction, for example, linear programs consisting of "small steps," adjusting the program for minimal student errors (i.e., so as to maximize reinforcement from "correct" responding), or fading of cues or prompts, (see, e.g., Taber, Glaser, and Schaefer, 1965). Control itself is not the issue here, but rather the degree of control and its adequacy.

Given the faith that with enough time and control over reinforcement contingencies, total control over behavioral forms can be achieved, it is surprising that Skinner himself (1948) should have called attention to a phenomenon he called "superstition." In essence, it means that irrelevant response components that happen to receive reinforcement remain integrated into the response repertoire of the learner as expressed by the "shaped" behavioral forms. Obviously, it implies that the achievable degree of control over any organism's behavior is less than total. In turn, that implies that a probabilistic rather than a deterministic view of causality as represented by S-R linkages must be maintained. Indeed, this is the view taken by Estes and Burke, and followers in what has come to be known as stimulus sampling theory (e.g., Estes, 1959). It is significant that this approach to a mathematical formulation of learning and/or behavior theory is neutral as to its empirical—that is to say, substantive psychological—underpinnings. We shall return to this point.

The issue of present concern is the validity of the prescriptions for instruction deriving from theoretical (or even atheoretical) descriptions of learning, and principally those stated in S-R terms. That validity would seem to be doubtful in view of the following examples of empirical results that are at variance with these prescriptions. While they happen to be aimed mainly at Skinnerian views, there is no intent to single them out for special criticism. The examples are intended to be illustrative—not exhaustive—and Skinner has been most explicit in his claims for instructional prescription. Similar examples damaging to other learning theoretical positions can be found quite easily. That evidence supporting certain theoretical propositions can also be found is true, but irrelevant to the present argument.

Cook (1963) has shown that the concept of "superstition" applies to its own originator. In support of this contention, Cook exhibits figures representing some previously published data (Cook and Spitzer, 1960). He shows that the performance of a "no overt practice" group was consistently and significantly superior to that of an "overt practice group." Skinner insists on the importance of overt responding by the learner, and also on the importance of reinforcing a correct response only *after* it has been made, while Cook shows that prompting students, that is, furnishing the correct response to them *before* they have had time to attempt it themselves, produces consistently and significantly superior performance.

Seidel and Hunter (1970), on the basis of massive and consistent data, have shown that prompting or confirmation (i.e., immediate reinforcement) do reduce error scores for within-learning measures, but have the reverse effect for criterion test scores (Figure 1). This evidence is damaging to the Skinner theory, while other facets of the findings support Harlow's (1959) Error Factor Theory. Kopstein has shown that neither the number of trials (Figure 2) nor the pacing or distribution of practice (Figure 3) determine amount learned. In both figures, it is shown that differences due to amount of study time (total learning time) are substantial and statistically significant ($p < .001$); differences *within* levels of study time are non-significant. That this is related only to the total amount of time available for study or practice, has been since then confirmed by Bugelski (1962) and others. Examples of this type could be continued to show that the accumulated experience leaves room for doubt that effective and efficient instructional strategies can be derived *solely* from behavioristic psychology.

Relations Between Learning Error and Criterion Test Error Under Prompting and Confirmation Conditions: Part III

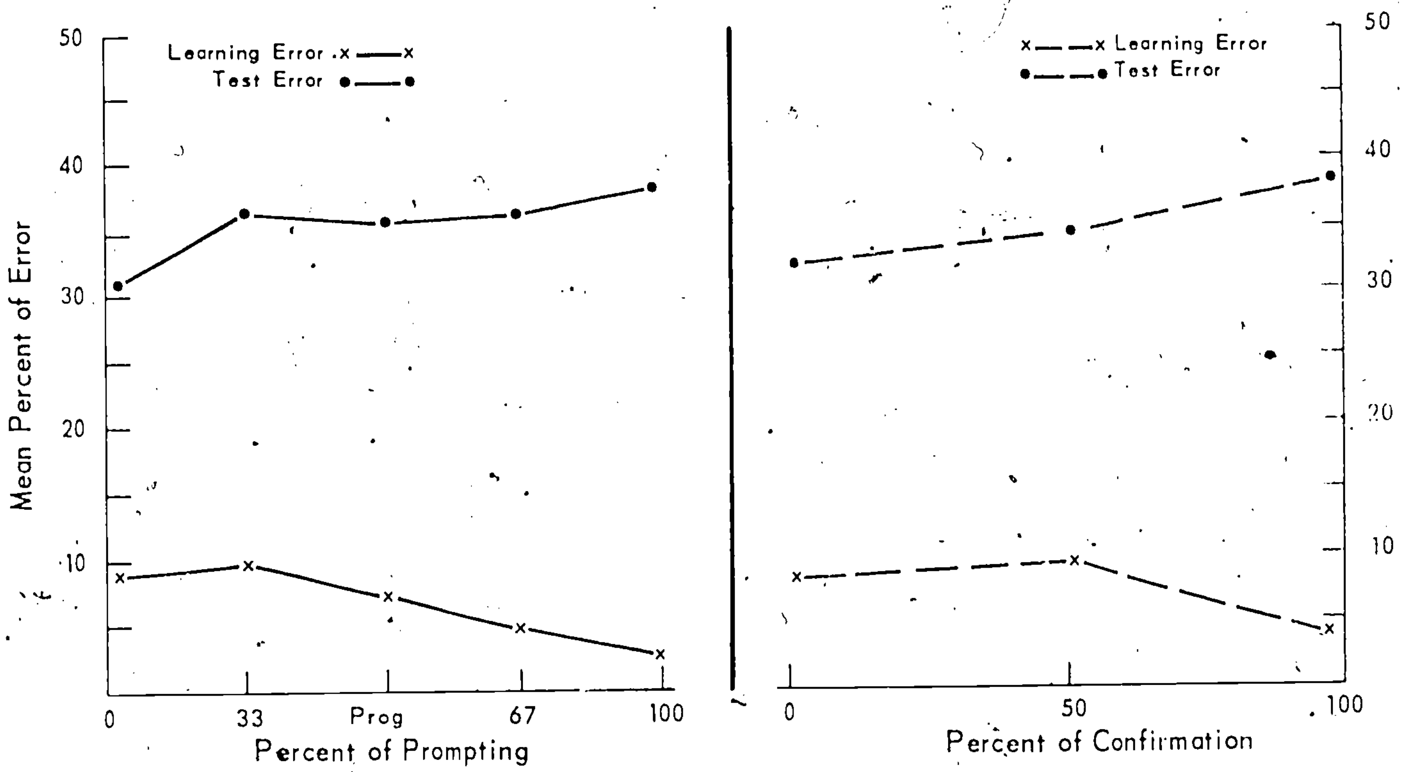

Figure 1

Melton's dicta notwithstanding, S-R psychology is not the sole relevant conceptual framework for education. A more broadly embracing model can be derived from cybernetics that Ashby (1956) described as follows:

> "Cybernetics deals with all forms of behaviour in so far as they are regular, or determinate, or reproducible. The materiality is irrelevant, and so is the holding or not of the ordinary laws of physics . . . *The truths of cybernetics are not conditional on their being derived from some other branch of science.*" (p. 1)

In short, here is an alternative conceptual approach—a formal one—with its own behavior theory that can partly substitute for and partly augment psychology as the basis for the technology of educational methods.

Cybernetics applied to instruction is a methodology for validating the concepts in any psychology of learning. It is a means for bringing together the descriptive and the prescriptive rules. It does not perforce exclude Skinnerian or any other concepts—although we have exhibited evidence that the operant control processes are not fully adequate for respectively describing and prescribing human learning and instruction. The advantage of cybernetics is that it provides a methodological arena within which the predictive (prescriptive) power of the substantive and formal concepts (namely, psychology of learning) can be properly evaluated. In this sense it is a meta-model for evaluating models within a discipline.

Cybernetics is an enormously complex topic with a vast web of implications, capable of being viewed from many vantage points. It is concerned (Wiener, 1961) with regulation and control in the animal and the machine. It is also a theory of process and of

Iterative Feedback Control

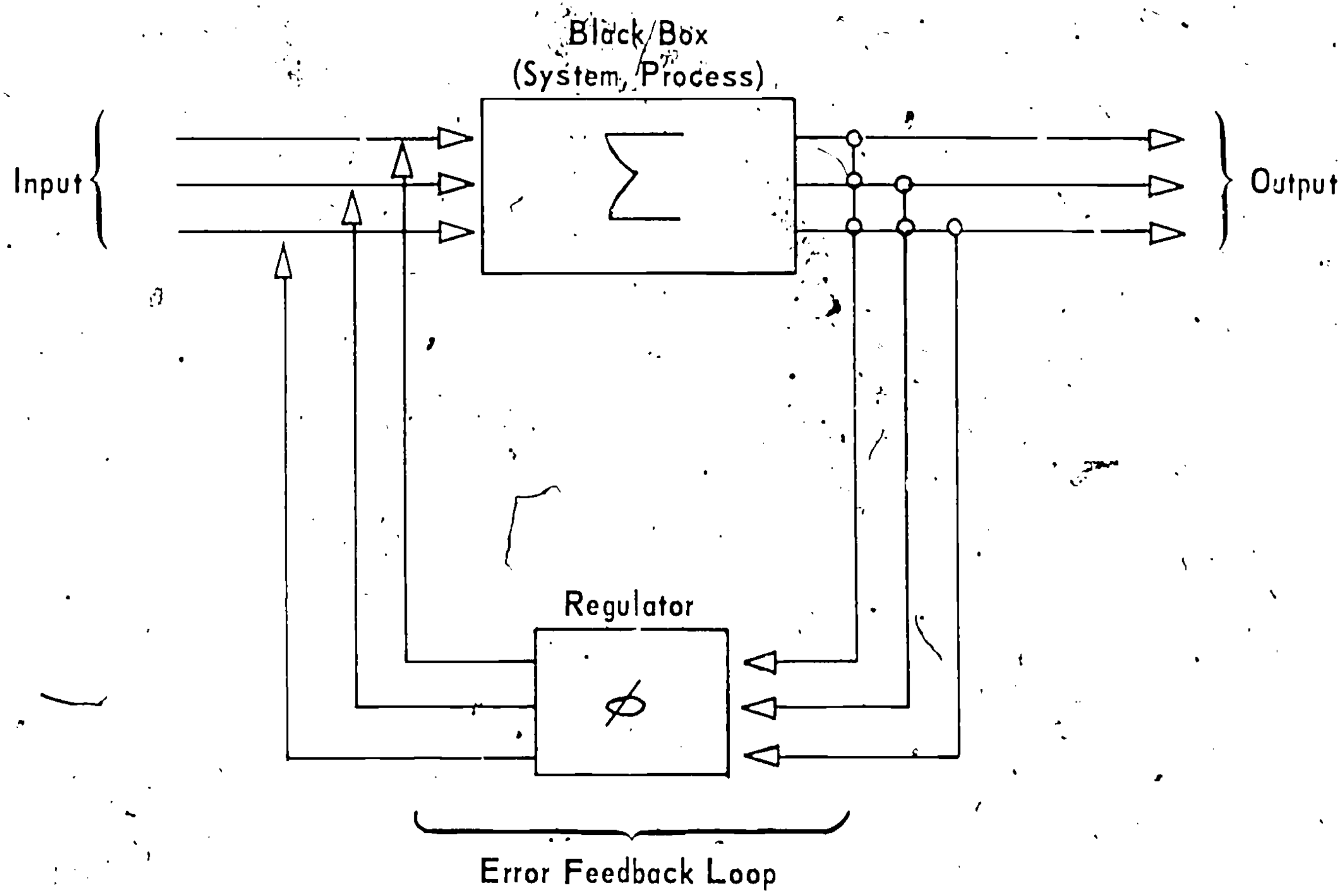

Figure 4

fed back to the input. In plain words, the teacher or regulator must be capable of diagnosing from the student's inaccurate answer the etiology of his confusion and so rephrase his question as to clarify it for the student who is thereby led to give a more nearly adequate response, and so forth.

The strength of the cybernetic view is that it does not prejudge concepts. In this sense, it is parallel to stimulus sampling theory. Concepts are allowed to develop or die as the system exercises them as inputs, transformations, or outputs. (This strength in one sense is also a weakness not unlike that of factor analysis—substantive constructs are imposed to give meaning within the discipline concerned.) It is a methodology for quantifying the characteristics of dynamic systems.

Stated thus, a cybernetic approach to instruction may well seem trite and obvious. If this is so, the brevity of the presentation must be blamed, since cybernetics is conceptually very rich. Thus Pask (e.g., 1960) has long pointed out that from a cybernetic point of view the interaction between a student and an instructional agent has the characteristics of a partially competitive, partially cooperative game for which models exist in mathematical game theory. Similarly, he has called attention to the fact that several levels of language are involved in the teaching-learning process (Pask, 1969). Most obviously, the learner's language (symbolic control) must be descriptive of the learning problem at hand, while the instructor's language must be descriptive of the student's language. Note that at least two levels of abstraction are implied. More familiar is the notion advanced by Gagne (1965) of eight hierarchically ordered types of learning. Though stated in S-R terminology, Gagne's conditions of learning are much more closely allied to a cybernetic view than to S-R (also, Kopstein, 1966). For example, it will be

Effects of Number of Trials on Amount Learned

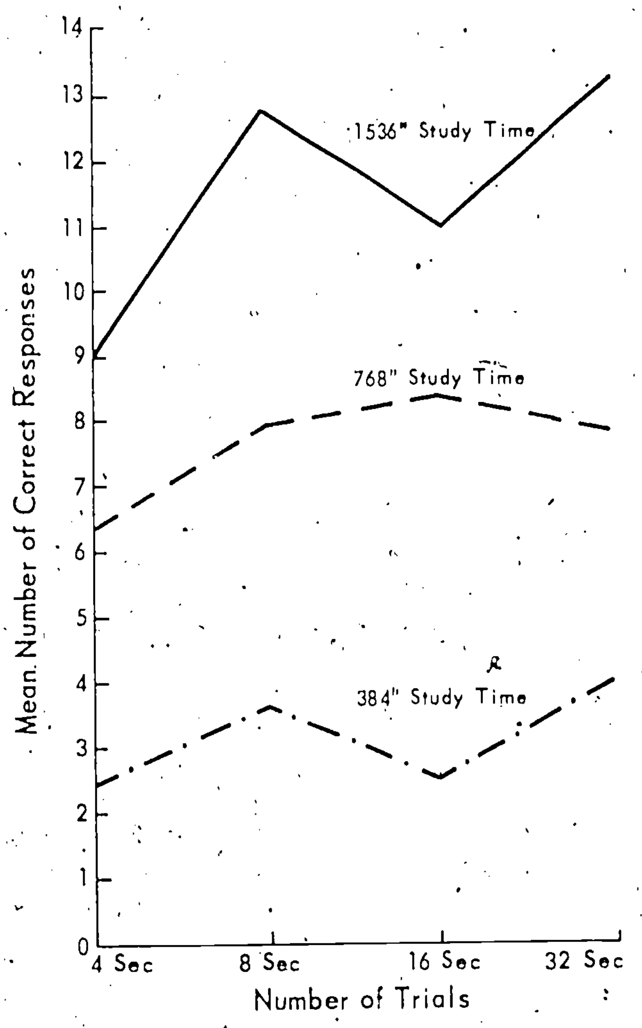

Figure 2

Effects of Distribution of Practice on Amount Learned

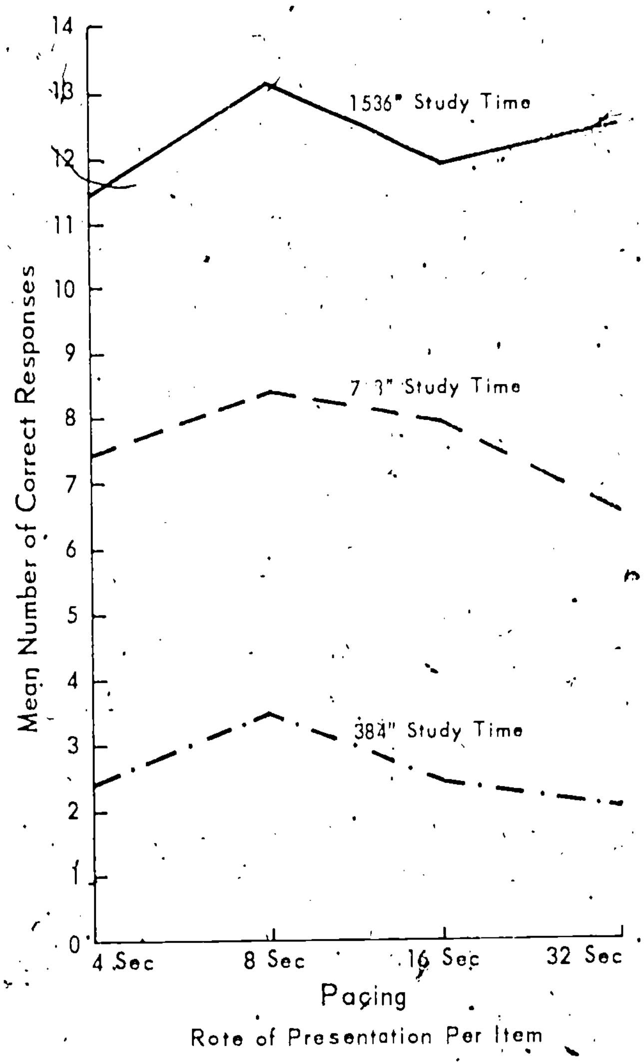

Figure 3

problem-solving, and, since science is nothing but formalized problem-solving, it is certainly a meta-theory of science and of rational ideational processes. It is conventional to represent the principles of iterative feedback control and regulation thus. A dynamic process—let it be the learning process of a student—forms a "black box." There are inputs of energy and of information to this black box as represented by the incoming arrows. There are also outputs of energy and of information as represented by the outgoing arrows. Measures of the degree to which obtained output deviates from expected output are fed back through control loops so as to reduce the discrepancy between expected and obtained output. The transformation of input to output itself is seen as a series of small, stepwise changes (transformations) over time as causative factors operate on successive states of the process (black box) in such a way as to converge on some desired state or outcome.

In a learning-instructional process the initial input—a question posed for the student—may produce an output or response by the student that is viewed as less than accurate. Simply restating the original question is unlikely to improve the situation, since no error (i.e., information about the degree of discrepancy and its dimensions) has been recalled that Gagne describes for each type of learning a set of requisite conditions within the learner and a set of conditions in the learning environment that serve to transform the state of the learner. In effect, each of Gagne's learning types amounts to an integration of behavior at a progressively higher level of organization—a basic notion in cybernetics.

Gagne's position is all the more fascinating because it appears to complement or to be complemented by the algorithmic view of learning, thinking, and instruction advanced by Landa (1968). In this view, the successive algorithmic steps generate specific logical conditions that yield to appropriate logical operators (conditions in the learning environment) so as to transform into a next set of logical conditions, and so forth. Landa's work, although still quite inaccessible to anyone not conversant with the Russian language, seems to be highly original and stimulating, and also thoroughly cybernetic in its orientation.

In summary, this paper has sought to arouse interest in the proposition that cybernetics provides an attractive alternative to, or a complement for, S-R learning or behavior theory as the scientific foundation for instructional methodology. Although it has not been possible to illustrate here how cybernetics prescribes instructional strategy, brief allusions have been made to some of the prominent representatives of a cybernetic approach.

Finally, the contraposition of "psychology or cybernetics" is open to differing interpretations. One may view cybernetics solely as a meta-model, that is, a general methodology of *applied* science, or one may view it as providing the explanatory substance (via its formal behavior theory) within the constraints imposed by the particular biological framework of a given species. The former view leads to a position that can be characterized as "psychology and cybernetics versus psychology alone." The latter view is expressed in the title.

Professor L.N. Landa[1] has provided the following comment on this issue:

> "... [It] seems to me debatable ... that cybernetics can substitute for psychology as the basis for the technology of educational methods.
>
> "It might be true if cybernetics were to be considered as the *general* basis for the development of educational methods, but instruction (and education in general) is a *specific* form of control (in the cybernetic sense). Therefore, in constructing an educational method it is necessary to take into consideration not only the general laws of control (they are necessary, but not sufficient), but specific ones as well. These latter ones can be identified and given to us by a psychology based on cybernetics. I would put the issue not as 'cybernetics instead of psychology' but as 'psychology with cybernetics as its general base'."

Perhaps it makes little immediate *practical* difference whether psychology is considered as a special case of cybernetics, or whether cybernetics is considered the meta-model for the science of psychology. At the current level of sophistication in the "technology of educational methods" efforts at theory development, experimentation, and explanation are likely to result in essentially the same kinds of activities. Clearly, either point of veiw will free researchers from theoretical and paradigmatic restrictions (cf., Kuhn, 1962) inherent in the behavioristic language of classical S-R psychology. Either view of cybernetics vis-a-vis psychology can beneficially affect the selection of data elements and their conceptual organization within the psychology of learning and its application to instruction.

[1] Personal communication.

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