PROBLEM-SOLVING: A BEHAVIORAL ANALYSIS
WITH IMPLICATIONS FOR INSTRUCTION

THESIS

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The paper documents the need for an effective technology to teach problem-solving. It asserts that a behaviorological analysis of problem-solving can speed the development of an effective technology to teach problem-solving behavior. A behaviorological definition of problem-solving is proposed. The history of behaviorological approaches to problem-solving is traced and suggestions are offered that may facilitate further empirical and theoretical work. One application of a behaviorological analysis to the teaching of problem-solving is illustrated by some preliminary data on the effectiveness of a technique for teaching a type of problem-solving behavior. Suggestions for further research are provided.
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NEEDED: AN EFFECTIVE TECHNOLOGY TO TEACH PROBLEM-SOLVING

If a problem may be defined as a maladaptive behavior/environment relation, then the human species now faces the ultimate problem. We behave in ways that may result in our ultimate extinction. We move faster and faster towards ecological disaster because we continue to mismanage our powerful physical technologies. We deplete natural resources, pollute air, water, and soil, and build weapons that, if detonated, would make our planet uninhabitable (Brubaker, 1972; Falk, 1971; Skinner, 1948, 1972; Snyder, 1971; Taylor, 1970). We must learn to manage our behavior so that we behave more adaptively. As the problems we must solve become increasingly complex, we can no longer depend upon "accident" to develop sophisticated problem-solvers. We must begin to systematically train problem-solving behaviors.

Unfortunately our educational system is failing us. Our schools are not effectively producing complex repertoires such as problem-solving skills. Educational advisory groups predict that our
schools' failure to teach critical thinking skills will have disastrous effects upon our economy, political system, and our culture's position of leadership in the world (U.S. National Commision on Excellence In Education [USNCEE], 1983; Carnegie Forum on Education and the Economy, 1986). According to the Carnegie Forum on Education and the Economy:

employers complain that graduates of secondary schools (and often graduates of colleges, too) find it hard to do the increasingly complex work required of them. They do not learn easily on the job, are unable to read complicated material, evaluate or make complex arguments, write well, or apply quantitative concepts and methods to unfamiliar problems.... too many students lack the ability to reason and perform complex nonroutine intellectual tasks. (pp. 15-20)

The National Commission on Excellence in Education concurs:

Many 17-year-olds do not possess the "higher order" intellectual skills we should expect of them. Nearly 40 percent cannot draw inferences from written material; only one-fifth can write a persuasive essay, and only one third can solve a mathematics problem requiring several steps. (p. 9)
As our economy continues to shift from an industrial to an information base, more and more of the jobs being created require critical thinking skills (Naisbitt, 1984). A complex and rapidly changing economy is a complex work environment. The individual worker must behave effectively in jobs which constantly require novel behavior/environment relations. Tools produce complex and novel changes in the worker's environment which in turn require more complex and increasingly novel behavior from the worker (Glenn, 1985).

In a rapidly changing economy workers must constantly retrain. Workers who have acquired problem-solving skills will learn faster and with less teacher assistance. When students have already acquired effective problem-solving skills, the teacher may teach them more efficiently. When students have effective problem-solving skills, they need less teaching because they can teach themselves. Less costly instructional materials may be devised and less instructional time will be needed to keep workers productive in a rapidly changing workplace.

The ultimate goal of any educational system is to produce student repertoires which make the student independent of
instructional arrangements contrived by the teacher (Skinner, 1966; Vargas & Fraley, 1984). A rapidly changing world presents novel problems that cannot be anticipated by the teacher. Students must be trained to think for themselves and to manage their own behavior. When students must depend on teacher-delivered prompts and reinforcers, they are less useful to others, as they cannot behave effectively once instruction has ended. Dependent students will be dependent workers, effective only if others in the organization provide constant supervision.

Educational advisory groups such as the Carnegie Forum and NCEE have correctly noted our failure to teach critical thinking skills as well as the potentially disastrous consequences of that failure. Unfortunately, these groups offer no new advice on how to teach skills such as problem-solving. An effective and efficient technology to teach problem-solving is needed. The teacher, just like any other worker, must have the proper technology to do the teaching job.

A science exists from which an effective technology to teach problem-solving could be developed. The science takes as its subject matter the relationships between an individual's behavior
and his or her environment. Thus, that science has concerned itself with the very nature of effective problem-solving: adaptive interactions between the individual and a rapidly changing and constantly novel environment. That science is behaviorology.
CHAPTER REFERENCES


CHAPTER II

PROBLEM-SOLVING AS A COMPLEX BEHAVIOR/ENVIRONMENT RELATION: A BEHAVIOROLOGICAL ANALYSIS

Two Criteria For A Theoretical Analysis Of Value To Teachers

A theoretical analysis can either promote or discourage the development of an effective technology to teach problem-solving. The development of a teaching technology will be facilitated by a theoretical analysis with the following characteristics: (a) elegant or parsimonious explanations and (b) explanations of problem-solving in terms of empirical events directly manipulable by teachers. Given that two explanations of problem-solving are equally supported by experimental evidence, the simpler or more parsimonious of the two explanations can be said to be more efficient as a guide for effective action. If a parsimonious explanation of problem-solving is not in terms of empirical, manipulable events, it provides little help to those who must teach problem-solving.

A behaviorological analysis is both parsimonious and in terms of
empirical events directly manipulable by teachers. The physical and biological sciences have produced powerful technologies by pursuing parsimonious explanations of their dependent variables in terms of observable, manipulable events. Parsimonious explanations of problem-solving, in terms of empirical events directly manipulable by teachers, can speed the development of an effective and efficient technology to teach problem-solving behavior.

A Behaviorological Analysis Of Problem-Solving

Problem-Solving as a Behavioral Process


A Functional Analysis

If problem-solving is an adaptive interaction it must be analyzed functionally, not structurally. The structure of an individual's problem-solving behavior changes as a function of changes in the problems to be solved. Though a problem situation is structurally identical for two different problem-solvers, it may be functionally
different with respect to the type of problem-solving behavior the two individuals will emit in that problem setting. To revise a famous quotation, a rose is not a rose is not a rose, with respect to its functional control over the behavior of different problem solvers with different histories of interactions with roses. Whether a problem solver approaches or avoids a rose, or even whether the rose exists for that individual, depends upon the problem solver's history of behavior with respect to previous rose-like objects.

Assuming Historical, not Hypothetical Causation

Behaviorologists assume that problem-solving occurs because of its adaptive function in the past environments of individual and species. The unique functional control of a problem over an individual's behavior is a product of that individual's unique history of interactions with problem situations. Behaviorologists do not require hypothesized cognitive structures and processes to explain why problem-solving occurs. Since a behaviorological analysis includes the contributions of each problem solver's idiosyncratic history to the current functional controls over an individual's behavior, behaviorologists do not require hypothesized constructs to explain why two different problem solvers are unequally likely to
solve the same problem. Behaviorologists consider cognitive structures and processes to be surrogates for the unique functional control of a problem situation over an individual's problem-solving behavior.

A Parsimonous Analysis

A behaviorological analysis is parsimonious. It does not rely upon hypothesized mediating processes and structures to explain human problem-solving. The focus of the analysis is upon the directly observable relationships between historical and current changes in the problem solver's environment and changes in the problem solver's behavior. A theoretical analysis which provides the simplest adequate explanation of problem-solving is to be preferred over more complex analyses. A parsimony criterion has proved to be a useful constraint upon the theoretical verbal behavior of scientists. By selecting the simpler of two equally effective explanations, scientists achieve greater efficiency in the control of their subject matters. Parsimonious explanations of problem-solving will speed the development of effective technologies to teach problem-solving.
An Analysis in Terms of Observable, Manipulable Events

Problem-solving as observable behavior can be functionally related to observable, manipulable events in the historical and current environment of the problem-solver. The external environmental events with which students interact are potentially controllable by teachers. An effective technology to teach problem-solving can arise from the study of functional relations between directly observable, manipulable environmental events and overt problem-solving behaviors.

Behaviorologists do not deny that problem-solving behaviors can occur covertly. However, a behaviorological analysis assumes:

(a) Covert problem-solving is usually first acquired as overt behavior. (b) Covert problem-solving is not different in kind from overt behavior. (c) Covert problem-solving can be made overt. (d) Covert problem-solving is maintained by the solutions it produces in the external environment of the problem solver (Skinner, 1974). The problem-solving processes described by behaviorologists can be directly observed during their acquisition and are potentially subject to control by teachers.
Implications for Teachers of Problem-Solving

A behaviorological analysis of problem-solving is both parsimonious and in terms of events directly observable and manipulable by teachers. By adopting such an analysis, educators can speed the development of an effective and efficient technology to teach problem-solving.
CHAPTER REFERENCES


CHAPTER III

PROBLEM-SOLVING DEFINED: A BEHAVIOR-BEHAVIOR/ENVIRONMENT RELATION


Problems And Problem Behaviors

A problem is a maladaptive behavior/environment relation. There are two types of problems: weak behavior and strong behavior problems. An individual has a weak behavior problem when a previously-shaped behavior which could produce reinforcing changes in a problem situation is not likely to occur. Such behavior can be called weak problem behavior. For example, a student is not likely to give the correct solution to an arithmetic task, when giving the correct solution could produce a reinforcing "Right!" from the teacher. The student has a weak behavior problem. An individual has
a strong behavior problem when a previously-shaped behavior which could produce punishing changes in a problem situation is likely to occur. Such behavior can be called strong problem behavior. For example, a student is likely to talk out of turn during a class discussion, when talking out of turn could produce a punishing reprimand from the teacher. The student has a strong behavior problem.

Problem-Solving Behavior

A problem-solving behavior is any behavior that changes a problem situation so that either: (a) a weak problem behavior is strengthened, producing reinforcing changes in the problem situation or (b) a strong problem behavior is weakened, avoiding punishing changes in the problem situation.

Strengthening Weak Problem Behavior

A student is given an arithmetic task with the following instructions: "Circle the number of forms on the right side of the worksheet that are equal to the written number on the left side of the worksheet." If the student is not likely to circle the correct number of forms when correct circling could produce a reinforcing "Right!" from the teacher, the student has a weak
behavior problem. A behavior that could produce a reinforcing "Right!" from the teacher is not likely to occur. However, if the student first names the number written on the left side of the worksheet and then counts the items to be circled, the student changes the problem situation so that he or she is now more likely to circle the correct number of forms, thus producing a reinforcing "Right!" from the teacher (Grimm, Bijou, & Parsons, 1973). Naming the number written on the left side of the worksheet and counting the forms to be circled on the right side of the worksheet are problem-solving behaviors, because they change a problem situation so that weak problem behavior occurs, producing a reinforcing change in the problem situation.

**Weakening Strong Problem Behavior**

If a student is likely to talk out of turn during a class discussion, when talking out of turn could produce punishing reprimands from the teacher, the student has a strong behavior problem. A behavior that could produce punishing comments from the teacher is likely to occur. However, if the student immediately records each instance of his or her talking out of turn, the student changes the problem situation so that he or she is now less likely to talk out of turn, thus
avoiding punishing reprimands from the teacher. Recording each instance of talking out of turn is a problem-solving behavior, because it changes a problem situation so that a strong problem behavior is less likely to occur, thus avoiding punishing changes in the problem situation (Broden, Hall, & Mitts, 1971).

A Behavior-Behavior Relation Defined

Together a problem-solving and problem behavior comprise a behavior-behavior relation in which: a problem solving behavior changes a problem situation, so that a problem behavior is either strengthened or weakened, in ways that produce reinforcing changes or avoid punishing changes in the problem situation. Counting and circling comprise a behavior-behavior relation in which: counting changes a problem situation, so that a student is more likely to circle the correct number of forms in an arithmetic task, thus producing a reinforcing “Right!” from the teacher. Talking out of turn and recording instances of talking out of turn comprise a behavior-behavior relation in which: recording instances of talking out of turn changes a problem situation, so that the student is less likely to talk out of turn, thus avoiding a punishing reprimand from the teacher.
When observed over time, a behavior-behavior relation can be described as two interlocking functional relations: (a) Changes in a problem behavior are produced by a problem-solving behavior and (b) those changes in the problem behavior make subsequent occurrences of the problem-solving behavior more likely. If a student is more likely to circle the correct number of forms that correspond to a written number, because the student first named the written number and then counted the forms to be circled, then that student may be more likely to name and count when asked to do similar tasks. Grimm et al. (1973) observed that students continued to name numbers and count forms overtly when given number identity tasks, even though the experimenter had ceased to reinforce those problem-solving behaviors. If a student is less likely to talk out of turn, because he records each instance of talking out of turn, then that student may be more likely to record future instances of talking out of turn. The self-recording behavior studied by Broden et. al. (1971) persisted even though it was not explicitly reinforced by the experimenter. A behavior-behavior relation is composed of two interlocking functional relations: (a) a problem-solving behavior produces increases or decreases in the occurrences of a problem
behavior, and (b) those changes in the problem behavior strengthen subsequent occurrences of the problem-solving behavior in similar problem situations.

Problem-Solving: A Behavior-Behavior/Environment Relation

Problem-solving is more than a behavior-behavior relation. The behavior-behavior relation is itself part of a larger behavior/environment relation. The behavior-behavior relation functions as a single behavioral unit, producing reinforcing changes or avoiding punishing changes in problem situations. A behavior-behavior relation, such as naming a number, counting the number of forms that correspond to that number, and circling that number of forms, is established and maintained as a behavioral unit by the reinforcing changes it produces in problem situations, such as teacher praise for correct solutions to number identity problems. To teach the behavior-behavior/environment relation called problem-solving, educators need accurate descriptions of the functional relationships between behavior-behavior relations and reinforcing changes in problem situations produced by those relations. Such an analysis could speed the development of an effective and efficient technology for teaching the different types
of behavior-behavior/environment relations called problem-solving.
CHAPTER REFERENCES


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CHAPTER IV

HISTORY OF BEHAVIOROLOGICAL APPROACHES TO PROBLEM-SOLVING

Three types of behaviorological analyses of problem-solving are found in the literature: theoretical, basic empirical and applied empirical. Each will be briefly reviewed. A comparison of the three types of analyses will reveal the lack of a common behaviorological terminology for the analysis of problem-solving. A functional terminology for the theoretical, basic, and applied analysis of problem-solving will be proposed by the author. Finally, the advantages of adopting a common functional terminology for the analysis of problem-solving will be discussed.

Theoretical Analysis of Problem-Solving

The first behaviorological analysis of problem-solving (Skinner, 1953) was theoretical, not empirical. Webster's New Twentieth Century Dictionary Unabridged (1977) defines theory as "a formulation of apparent relationships or underlying principles of certain observed phenomena which has been verified to some degree" (p. 1893). According to Skinner (1969) his writings are theoretical
in the sense that they provide "an interpretation of familiar facts... in the light of a scientific analysis" (pp. vii-viii). Skinner's analysis of problem-solving is theoretical, in that, his writings are verbal extensions of principles formulated from an empirically-based experimental analysis of nonhuman behavior. In a series of theoretical papers beginning in 1953 and extending to the present (1957, 1966, 1968, 1969, 1974, 1984), Skinner has continued to develop his initial analysis. A brief summary of that analysis follows.

Two Types of Problem-Solving

Two different types of problems led Skinner to distinguish between two types of problem-solving: self-control and thinking (1953). Motivative problems give rise to the type of problem-solving he has labeled self-control, while discriminative problems give rise to the type of problem-solving he has labeled thinking (1953, 1969, 1984). 3,4

Motivative Problems

An individual has a motivative problem when a behavior that could produce reinforcers is too weak or a behavior that could produce punishers is too strong because of defective motivative
controls over that behavior. There are two types of defective motivative controls: (a) The immediate and delayed postcedents of a behavior may have conflicting effects on the subsequent probability of that behavior and (b) establishing operations may be defective for a problem behavior.

**Defective postcedent controls.**

Conflicting positive and negative consequences, of either an intellectual or ethical nature, are especially likely to raise problems of this sort—for example, when a strongly reinforced response has deferred aversive consequences or when immediate aversive consequences conflict with deferred reinforcers.

(Skinner, 1984, p. 590)

For example, smoking is a strong motivative problem behavior because the aversive postcedents of smoking are too delayed to function as punishers, while its immediate postcedents are highly reinforcing. Even when smoking has produced delayed aversive consequences such as the surgical removal of tracheas and lungs, some individuals continue to smoke. Practicing finger exercises is a weak motivative problem behavior for musicians because the improved technical performance produced by the practice is too
delayed to function as a reinforcer for practicing, while the sounds immediately produced by the repetitive practice usually function as punishers. Smoking and practicing finger exercises are problem behaviors because of their defective postcedent controls.

**Defective establishing operations.** A problem behavior may be strong or weak due to the effects on that behavior of various establishing operations. For example, aggressing may become a strong problem behavior when (a) previously delivered food is no longer delivered to a food deprived organism or (b) an organism contacts tissue-damaging stimuli (Azrin, Hutchinson, & Hake, 1966; Azrin, Hutchinson, & McLaughlin, 1965; Mowrer & Jones, 1943). Either of these operations can increase the probability of aggressive behaviors. Studying may become a weak problem behavior following a lengthy study session.

**Discriminative problems**

An individual has a discriminative problem when a problem behavior is too weak or too strong because of defective discriminative controls for that behavior. As Skinner (1953) has stated:

There appears to be no problem for the organism which is not in
a state of deprivation or aversive stimulation, but something more is involved. The hungry organism eating ravenously is perhaps disposing of a problem, but only in the trivial sense. In the true "problem situation" the organism has no behavior immediately available which will reduce the deprivation or provide escape from aversive stimulation ... a response exists in strength which cannot be emitted .... Discriminative stimulation may be needed to determine the form or direction of the response, or the response may require external support or instrumentation which is lacking. (p. 246)

Thus, a discriminative problem behavior is too weak or too strong, not because of defective motivational controls, but because its discriminative controls are defective.

Consider the following example of a problem behavior that is weak because of defective discriminative controls: A teacher places two written numbers in front of the student, a "6" and a "9." The teacher says "point to number six." If the student points to the correct number, that behavior will produce teacher praise. The student may want to point to number six (teacher praise would function as a reinforcer for that behavior), but nevertheless points
to number nine. In more technical terminology, the establishing operation for pointing to correct numbers is strong, but the behavior of pointing to the correct number is weak due to defective discriminative controls. A student might strengthen the weak behavior by saying "the stem of number six goes up," a self-instruction that may provide the necessary discriminative stimulus for the problem behavior.

Consider the following example of a problem behavior that is strong due to defective discriminative controls: Verbal behavior incompatible with studying may be likely because of the strengthening effects of the discriminative stimuli provided by other's verbal behavior. Behavior other than studying is likely to produce punishing consequences such as the conditioned emotional responding called guilt. Thus study halls and libraries enforce no talking rules to eliminate discriminative stimuli for verbal behavior incompatible with studying.

**A Functional Classification of the Two Types of Problem-Solving**

Skinner has provided a functional classification of problem-solving according to the two types of defective controlling variables for a problem behavior: motivative and discriminative. He
has labeled these two types of problem-solving as self-control and thinking.

Problem-solving is a behavior-behavior relation between two behaviors of the same individual in which: (a) a problem-solving behavior changes the probability of a problem behavior and (b) changes in the problem behavior increase the subsequent probability of the problem-solving behavior. The behavior-behavior relation is itself maintained by the reinforcing changes it produces in the problem setting. Problem-solving may be classified as motivative if the problem behavior is weak or strong due to defective motivative controls. Problem-solving may be classified as discriminative if the problem behavior is weak or strong due to defective discriminative controls.

Empirical Analysis of Problem-Solving: Basic and Applied

Webster's New 20th Century Dictionary Unabridged (1977) defines empirical as "relying or based solely upon experiments or experience" (p. 594); Johnston and Pennypacker (1975) define empiricism as "the doctrine that knowledge can be gained from experience" (p. 22). Empirical analyses of problem-solving are descriptions of the functional relations between two directly
observed events. A basic analysis differs from an applied one in the kinds of controls over the behavior of the analyst (Baer, Wolf, & Risley, 1968; Baer, 1981). Basic analyses are done because they produce new descriptions of functional relationships (in lay terms: new knowledge), while applied analyses are done because they produce new technologies for the service of specified client populations.

Basic Empirical Analyses

Basic empirical analyses of the two types of problem-solving described by Skinner, self-control and thinking, can be found in the behaviorological literature. However, basic researchers have developed a terminology for the description of problem-solving that differs somewhat from that found in the theoretical literature.

Self-Control or Motivative Problem-Solving

A number of basic empirical analyses of motivative problem behavior have been done (Ainslie, 1974; Green & Snyderman, 1980; Grosch & Neuringer, 1981; Hayes, Kapust, Leonard, & Irwin, 1981; Logue, Pena-Corral, Rodriguez, & Kabela, 1986; Logue, Pena-Corral, & Mauro, 1984; Lopato & Lewis, 1985; Mazur & Logue, 1978; Rachlin & Green, 1972; Synderman, 1983; Vaughan, W., 1985). According to
Rachlin (1974), "subjects show self-control when they prefer larger rewards in the future to smaller rewards in the present or symmetrically avoid greater pain in the future in return for lesser pain in the present" (p. 94). Other basic researchers have defined self-control as "the choosing of the delayed larger reinforcer" (Lopato & Lewis, 1985, p. 64) or as "the selection of a larger delayed reward over a smaller, more immediate one" (Green & Synderman, 1980, p. 146). Not one of the basic researchers cited defines self-control as a behavior-behavior/environment relation, involving both a problem-solving and problem behavior.

And yet, empirical researchers have failed to demonstrate the occurrence of self-control, in the absence of some type of problem-solving behavior. For example, when pigeons were (a) presented with a choice between immediate but limited access to grain and delayed but lengthier access and (b) not given the opportunity to emit problem-solving behaviors, they almost always chose the immediate access to grain (Lopato & Lewis, 1985; Mazur & Logue, 1978; Green & Synderman, 1980; Vaughan, W., 1985; Logue et al, 1984).

However, several basic researchers have demonstrated the
occurrence of self-control as a behavior-behavior/environment relation. Rachlin and Green (1972) provided pigeons with the opportunity to emit a commitment response. A commitment response is a response that prevents a later choice between an immediate but short duration access to grain and longer but delayed access, so that only the longer delayed access can be produced. When given the opportunity to emit a commitment response, the pigeons would consistently do so. The commitment response appeared to function as a problem-solving behavior in a motivative problem-solving process, in that: (a) The commitment response changed the environment so that a behavior with defective motivative controls was more likely to occur and produce reinforcing changes in a problem situation, and (b) the commitment response was itself maintained by its effect on the problem behavior. Rachlin and Green demonstrated that the commitment response extinguished when it did not preclude the later choice between immediate, short duration grain access and delayed, lengthier access to grain. Thus, basic empirical researchers have been able to demonstrate the occurrence of self-control as a behavior-behavior/environment relation, a definition consistent
with that found in the theoretical literature. (See also, Ainslie, 1974; Grosch & Neuringer, 1981; Hayes, et al., 1981.)

Basic research on self-control in humans (Logue et al., 1986) has also provided tentative data on the occurrence of self-control as a behavior-behavior/environment relation. When human subjects were given a choice between two levers, one producing a small immediate monetary pay-off and the other a larger but delayed payoff, the humans were more likely to press the lever producing the larger but delayed consequence. Although the human subjects were not provided with the opportunity to emit a commitment response, they did report emitting behaviors such as timing the relative delays to payoff of the two levers and calculating the relative amount of money to be earned by pressing one lever instead of the other. These behaviors, if they did occur, may have functioned as problem-solving behaviors for a motivative problem behavior.

If basic researchers systematically adopted Skinner's theoretical definition of self-control as a behavior-behavior/environment relation, they might begin to design experiments that would allow them to observe directly behaviors such as calculating and timing and to determine whether these behaviors are indeed functioning as

**Thinking or Discriminative Problem-Solving**

A number of basic empirical analyses of discriminative behavior-behavior/environment relations may be found in the behaviorological literature. However, these processes are never referred to as problem-solving. Instead, basic researchers have adopted a variety of labels for discriminative problem-solving behaviors: *mediating* (Ferster & Skinner, 1957; Laties, Weiss, Clark, & Reynolds, 1965), *precurrent* (Parsons, Taylor, & Joyce, 1981), and *self-instruction* (Vaughan, M.E., 1985).

**Mediating behavior.** In their adoption of the term *mediating behavior*, Laties, Weiss, Clark, and Reynolds (1965, p. 107) cite the following Ferster and Skinner definition: "behavior occurring between two instances of the response being studied... which is used by the organism as a controlling stimulus in subsequent behavior" (1957, p. 729). Laties et al. observed that rats placed on a DRL reinforcement schedule emitted stereotyped behaviors such as tail gnawing between lever presses. Lever presses on a DRL schedule are only reinforced after some interval of time in which no lever pressing has occurred. Thus any behavior other than lever
pressing, with a duration greater than the duration of the DRL interval would be correlated with reinforced lever presses on a DRL schedule. Such behavior could come to function as discriminative stimuli for lever presses occurring after long interresponse times. To determine if the rats' tail-gnawing was indeed functioning as a discriminative stimulus for lever presses with long IRTs, Laties et al. prevented the tail gnawing from occurring. They observed a subsequent decrease in reinforced lever pressing as rats began to press after pauses insufficient to produce reinforcers. In a later study, Laties, Weiss, and Weiss (1969) observed repeated increases and then decreases in number of reinforced responses on the DRL schedule as a function of the occurrence and non-occurrence of various collateral behaviors such as grid bar licking and wood gnawing. These collateral behaviors appeared to be functioning as mediating behaviors in discriminative problem situations, producing discriminative stimuli for reinforced lever presses on DRL schedules. Laties et al. (1965; 1969) also demonstrated that the rats' various collateral behaviors were themselves maintained by their effects on reinforced lever pressing. When lever pressing was placed on an extinction schedule, the rats' differing collateral
behaviors also decreased. Thus Laties and colleagues appear to have empirically demonstrated the occurrence of discriminative problem-solving in rats. Discriminative problem-solving is a behavior-behavior relation between two behaviors of the same individual, in which: (a) A problem-solving behavior produces discriminative stimuli for a problem behavior with defective discriminative control; (b) the problem-solving behavior is itself increased by subsequent changes in the problem behavior; and (c) the behavior-behavior relation is itself maintained by the reinforcing changes it produces in the discriminative problem situation.

Bruner and Revusky (1961) presented human subjects with a discriminative problem situation similar to the ones Laties et al. presented to rats, lever pressing on a DRL schedule. Human subjects who emitted stereotyped collateral behaviors (regular patterns of pressing on an unreinforced lever) were more likely to pause between presses on the DRL lever for the length of time necessary to produce monetary reinforcers, than human subjects who did not emit this collateral behavior. Bruner and Revusky demonstrated that lever pressing on the unreinforced lever was maintained by its effects on the DRL lever pressing. When the DRL presses were
placed on an extinction schedule, collateral pressing on the second lever also decreased. The humans' collateral behavior appeared to be functioning as problem-solving behavior in a discriminative problem-solving process, as it was producing discriminative stimuli for lever pressing reinforced on the DRL schedule.

Blough (1959) observed that pigeons working on a delayed matching-to-sample task were emitting sample-specific collateral behaviors during the interval between sample offset and the opportunity to make a matching response to one of two comparison stimuli. For example, one pigeon pecked the top of the sample key rapidly in the presence of a continuously lit sample, but when the sample was lit with a flickering light the pigeon backed away from the sample and began waving its head quickly back and forth. The pigeons' sample-specific collateral behaviors appeared to function as discriminative problem-solving behaviors, producing discriminative stimuli for the pigeons' subsequent pecking of a matching comparison stimulus. When the pigeons emitted sample-specific collateral behaviors, they were more likely to make a reinforced peck on the matching comparison stimulus than when the pigeons did not emit the sample-specific collateral behaviors.
Blough noticed that the birds' sample-specific behaviors were producing visual stimuli in an aluminum panel surrounding the sample key. Blough suspected that the visual stimuli had a discriminative function, as they were correlated with reinforced matching. When he removed the aluminum panel from the sample key, thus eliminating the sample-specific stimuli, the birds' sample-specific behavior ceased to occur and accurate matching decreased. When he replaced the panel, the birds' sample-specific behavior again began to occur, with a corresponding increase in the birds' accurate matching. Thus, Blough demonstrated that the pigeons' sample-specific collateral behaviors were indeed functioning as problem-solving behaviors in a discriminative problem-solving process, producing discriminative stimuli that increased the probability of a weak problem behavior with defective discriminative controls.

Precurrent behavior. Parsons et al. (1981) examined the effects of explicitly trained sample-specific behavior on the delayed matching performance of young humans. When the children were trained to press a top or bottom panel depending upon the visual intensity of a lit sample key (the sample-specific behavior), they
matched more accurately after delays up to 10 seconds than when they were prohibited from emitting that sample-specific behavior. The sample-specific behavior appeared to be functioning as problem-solving behavior, producing discriminative stimuli for the subjects' accurate matching, a discriminative problem behavior. Parsons et al. termed the trained collateral behavior *precurent*, because "it prompts a reinforceable instance of the current operant, and reinforcement of the current operant maintains both the precurrent and current operants" (p. 254). *Precurrent operant* is a term first coined by Skinner to refer to the problem-solving behavior in a discriminative problem-solving process (1953, 1957, 1968, 1969). Parsons et al. cite an unpublished pilot study (Parsons, Goehring, & Waugh, 1979) on the maintenance of the childrens' sample-specific behavior. In their pilot study Parsons et al. demonstrated that the childrens' sample-specific behavior would persist, even when it was no longer manded by the experimenters. Thus, childrens' collateral behavior has been shown to increase the accuracy of a discriminative problem behavior and the collateral behavior appears to be maintained by its' effects on the problem behavior. Unfortunately, as Parsons et al. did not attempt to
extinguish the childrens' matching behavior, we cannot say whether the childrens' collateral behaviors would have decreased, if they had no longer affected the probability that accurate matches would be reinforced.

**Self-Instruction behavior.** M.E. Vaughan (1985) obtained more accurate performance from children given repeated acquisition button pressing tasks when she had previously asked the children to describe their button pressing behavior and its consequences as they worked, than when she did not ask the children to describe their own behavior. The childrens' self-descriptive behavior appeared to function as problem-solving behavior in a discriminative problem-solving task, producing discriminative stimuli for accurate patterns of button pressing. The self-descriptive behavior continued to occur even when not requested by the experimenter, suggesting that it may have been maintained by its discriminative effect upon the reinforced button pressing. However, like Parsons et al. (1981), Vaughan did not attempt to extinguish the childrens' button pressing, so we cannot say whether their self-descriptive behavior was in fact maintained by its effect on the reinforced button pressing. Vaughan termed the childrens' problem-solving
behavior: *self-instruction* She defines self-instruction as follows:

Self-instruction appears to be a particular case of what Skinner (1969) has referred to as 'rule-governed behavior' (p. 149). People learn to be affected by a description of a contingency somewhat as they would be affected by the contingency itself. Skinner has referred to such as description as a 'rule' or more technically, as a 'contingency-specifying discriminative stimulus' ... in self-instruction, the person describes contingencies and then reacts to the description as if it were given by someone else. (p. 175)

Thus self-instruction is Vaughan's term for a verbal problem-solving behavior that produces instructional stimuli in a discriminative problem-solving process.

Defining *self-instruction* as problem-solving behavior may not be useful to the problem-solving analyst. Skinner (1969) defines an *instruction* as a contingency description and a rule as a description of the relation between a response and its consequences. He also states that "any actual formulation of the relation between a response and its consequences *may* (italics added), of course, function as a prior controlling stimulus" (p. 147) and "descriptions
of contingencies are often effective" (p. 114). Skinner's definitions of rules and instructions do not specify that a rule or instruction must have an effect upon the behavior it specifies. Glenn (1987) argues that the term rule should be defined independently of its' effects upon a behavior for the following reasons: (a) "... good scientific practice requires that events entering into functional relations be independently specified...

(p. 30) and (b) defining a rule as an objective environmental event (independent of its' effects upon a behavior) is useful because contingency-specifying stimuli "... may enter into many different kinds of relations" (p. 30). See Schlinger and Blakely (1987) and Blakely and Schlinger (1987) for a discussion of some possible function-altering effects of contingency-specifying stimuli.

There are numerous studies of both motivative and discriminative problem-solving to be found in the basic empirical literature. However, different terminologies for the analysis of problem-solving have evolved within the basic and theoretical behaviorological communities. The theoretical term problem-solving has not been adopted by basic analysts. Basic empirical analysts, unlike their theoretical counterparts, seldom
define the term *self-control* as a behavior-behavior/environment relation. Basic researchers have adopted a variety of terms for discriminative problem-solving behavior, such as *mediating, precurrent operant, and self-instruction*. Although their terms differ from those found in theoretical analyses, basic researchers have, in general, defined discriminative problem-solving behavior according to its observed effects on problem behavior. Thus, basic researchers have adopted a functional approach to their empirical analysis of behavior-behavior/environment relations that is consistent with Skinner's theoretical analysis.

**Applied Empirical Analyses.**

Applied research is done because it evaluates the effectiveness with which behavior change procedures produce behavioral processes of benefit to a client population. As Catania (1975, 1976, 1984) has previously noted, behaviorologists have failed to make a clear distinction between behavior change procedures and the behavioral processes produced by those procedures. The terms *procedure* and *process* are close etymological relatives. The root word for process, the Latin *processus*, is the past participle of *procedere*, the root word for *procedure* (Webster's New 20th Century Dictionary
Webster’s defines a procedure as “the act, method, or manner of proceeding in some process or course of action, a particular course of action or way of doing something” (p. 1434). A procedure can be defined as a series of instructions followed in a regular, orderly, and definite way. A procedure is usually named for its' previously produced outcomes. Thus procedures that typically produce cakes are called cake-making procedures. A behavior change procedure specifies changes to be made in the independent variables of a behavior that has been targeted for change. For example, a reinforcement procedure might specify that teacher approval (independent variable) be delivered immediately contingent upon a student's on-task behavior (a behavior targeted for change). A reinforcement procedure typically produces the behavioral process called reinforcement.

Webster’s defines process as “a continuing development involving many changes” (p. 1434). A behavioral process may be defined as a functional relationship between orderly changes in a behavior and orderly changes in one or more of the controlling variables for that behavior (Catania, 1984). For example, Catania
increases in likelihood, then the term reinforcement may be applied" (p. 193). If a behavior change procedure is effective it will establish a desired behavioral process. The independent variables manipulated procedurally will prove to be controlling variables for a targeted behavior. For example, if on-task behavior increases as a function of immediately contingent teacher approval, the previously described reinforcement procedure has effectively produced a reinforcement process.

Unfortunately, reinforcement procedures, like other procedures, are not always effective. Reinforcement procedures do not always produce reinforcement processes. A teaching procedure effective in changing one student's behavior may not be effective in changing another student's behavior. When environmental conditions change, procedures can become ineffective. For example, a cake recipe designed to produce cakes at low altitudes may not be effective at high altitudes. An event that functions as a reinforcer for one student's behavior may not function as a reinforcer for some other student's behavior. Cakes may not rise and student on-task behavior may not increase, even though cake-making and reinforcement procedures were correctly followed. But procedures can be modified
so that they remain effective in new situations. A cake-making procedure can be altered by changing the amount of baking powder or oven setting called for by that recipe; reinforcement procedures can be altered by specifying different consequences to be tried as reinforcers or different operations for changing the reinforcing value of those consequences. Ineffective teaching procedures may be altered so that teaching processes are facilitated. [See Fraley & Vargas (1975); Johnston (1976); and Skinner (1968) for functional definitions of teaching as arrangements of environmental conditions which expedite student behavior change.] By distinguishing between behavioral processes to be produced and the behavior change procedures that may or may not be effective in producing those processes, applied behaviorologists can more effectively adapt their procedures to new clients and environments. Instead of saying "Reinforcement doesn't work. I informed the student that he was correct immediately after he answered my question correctly but his behavior didn't change," the applied behaviorologist can say "My reinforcement procedure didn't work. How can I modify my procedure to make it effective?"

In the applied literature problem-solving research is usually
classified according to the type of procedure that is to be evaluated. The problem-solving process to be produced is seldom specified by the applied researcher. (For an exception see Grimm, Bijou, & Parsons, 1973). The following procedures are typically studied: self-assessment, self-reinforcement, self-punishment, self-determined criteria, and self-instruction. The behaviors targeted by these procedures will provide instructions, assessments, or criteria for some problem behavior. The term self merely indicates that the targeted problem-solving behaviors (instructing, assessing, and criteria setting) as well as their targeted problem behaviors will be emitted by the same individual, a client with the targeted problem behavior. A procedure may establish assessing, criterion setting, or instructing behaviors, but those behaviors may still not function as problem-solving behaviors. A problem-solving procedure is considered effective only if it establishes assessing, criterion setting, and instructing as problem-solving behaviors for a targeted problem behavior. The behaviors produced by effective problem-solving procedures may function as problem-solving behaviors in either discriminative or motivative problem-solving processes. Problem-solving procedures
are usually referred to as self-control or self-management procedures in the applied literature (O’Leary & Dubey, 1979; Rosenbaum & Drabman, 1979). The author could only find one study in which the term *problem-solving* was used by an applied researcher (Grimm, Bijou, & Parsons, 1973).

**Self-Assessment**

A self-assessment procedure requires the training of behaviors by which subjects measure the quantity or quality of their own problem behavior (O’Leary & Dubey, 1979). A self-assessment procedure usually includes both self-recording and self-evaluation procedures. To self-record, an individual simply observes and records the targeted behavior; to self-evaluate, the individual compares the observed behavior to some externally provided criterion (Rosenbaum & Drabman, 1979).

However, self-recording necessarily involves some degree of self-evaluation. To self-record the percentage of intervals in which a problem behavior occurred or to self-record the products of a problem behavior, the self-assessor must compare an observed problem behavior or its product to some criterion defining that behavior or product (such as a criterion defining on-task work...
behavior or a complete sentence). For example, to self-record the percentage of intervals of on-task work behavior or to self-record the number of complete sentences written, a student must compare the observed behavior or product to a criterion defining on-task work behavior or a complete sentence (Ballard & Glynn, 1975; Seymour & Stokes, 1976). Thus, self-recording typically involves evaluating as well as observing and making a record of problem behaviors or behavioral products. Self-recording or self-assessment are interchangeable terms describing the various behaviors required to produce accurate self-records of a problem behavior.

Is self-assessment training an effective way to establish motivative problem-solving behaviors? In other words, does self-assessment training effectively produce problem-solving processes? No firm conclusions can be drawn from applied studies of self-assessment training. Turkewitz, O'Leary, and Ironsmith (1975) found that their self-assessment training procedures had no effect upon the disruptive behaviors of children ages 7-11. Ballard and Glynn (1975) obtained similar results. Self-assessment training did not increase the number of sentences children wrote during an
assigned writing time. However, Gottman and McFall (1972) found that teaching self-assessment behaviors increased the participation of high school students during class discussions; while Sagotsky, Patterson, and Lepper (1978) demonstrated that self-assessment training increased the number of mathematics units completed by elementary school students.

How can self-assessment procedures be modified so that they consistently produce problem-solving involving motivative problem behaviors? The self-assessment procedure must specify operations that will establish self-assessing behaviors as problem-solving behaviors for targeted problem behaviors. Self-assessing can be established as problem-solving behavior by making established reinforcers contingent upon: (a) the subject's accurate self-assessment (b) of desired changes in a problem behavior. [This procedure has been termed correspondence training by Israel (1978)].

By providing reinforcing consequences for a correspondence between desired changes in a problem behavior and a subject's accurate self-assessment of those changes, the interventionist can establish a behavior-behavior relation, in which self-assessing functions as a problem-solving behavior for a targeted problem behavior.
For example, Baer, Stokes, Holman, Fowler, and Rowbury (1981) taught children to accurately count each worksheet page they completed. The children counted by moving beads on a small bracelet. At the end of each work session the teacher delivered praise for: (a) the number of workbook pages each student completed (desired products of the problem behavior), (b) accurate counts of the number of workbook pages completed, and (c) accurate counts of increases in the number of workbook pages completed (accurate self-assessment of desired changes in the problem behavior). The childrens' on-task behavior increased when they were allowed to use the bracelets and decreased when the bracelets were removed. Baer et al.'s procedures were effective in establishing self-assessing (bead counting) as problem-solving behavior for a targeted problem behavior (completing assigned work).

Bolstead and Johnson (1972) made points contingent upon childrens' accurate self-assessment of disruptive behaviors, with accurately reported lower rates of disruptive behavior earning more points than accurately reported higher rates. Points were delivered at the end of each 30 minute observation session. Points could be exchanged for items such as pencils, notepads, and childrens'
readers. The children's disruptive behavior decreased. Seymour and Stokes (1976) worked with adolescent girls labeled as persistent offenders and incarcerated in the maximum security unit of a treatment center. The experimenters made tokens contingent upon the girls' accurate self-assessment of their work behavior. Accurate self-assessment of on-task work behavior earned tokens, with higher reported percentages on-task earning more tokens than lower reported percentages on-task. Initially, tokens were delivered at the end of each three hour work session; at a later point in the study the tokens were delivered at the end of each work day. The tokens could be exchanged for activities and privileges such as movies, passes, and clothing. The percentage of time in which the girls were observed to work increased. Turkewitz et. al. (1975) made points contingent upon children's accurate self-assessment of their academic and social behavior in an after-school reading program. High self-ratings of academic and social behavior earned more points than low self-ratings, as long as the ratings were accurate. Points were delivered at the end of each 15 minute observation session. The points were exchangeable for candy, toys, and snacks. The childrens' disruptive behaviors
decreased.

Note that in none of the four previously described studies did delivery of tokens and praise immediately follow each desired change in a problem behavior. In applied settings it is often difficult to make programmed consequences immediately contingent upon a targeted behavior. A number of basic empirical studies have demonstrated that the delayed consequences of a behavior have a lesser effect upon that behavior than the more immediate ones (Sizemore & Lattal, 1977; Williams, 1976). Delayed consequences could become more effective in changing a problem behavior if the teacher or therapist could establish problem-solving behavior that would mediate the delayed consequences of the problem behavior.

Two of the studies previously discussed (Bolstead & Johnson, 1972; Seymour & Stokes, 1976) compared the effects of two different procedures on a problem behavior: (a) delayed point/token deliveries delivered contingently upon a desired change in the problem behavior and (b) point/token deliveries immediately delivered for accurately assessing a desired change in a problem behavior. When Bolstead and Johnson made points immediately contingent upon childrens' accurate self-assessment of decreases in disruptive behavior, the
children's rates of disruptive behavior were lower than when those points were made a delayed consequence of decreases in the children's disruptive behavior. Seymour and Stokes made tokens immediately contingent upon adolescent girls' accurate self-assessment of increases in their work behavior; the girls' percentages of work behavior were higher than when the experimenters made tokens a delayed consequence of increases in the girls' work behavior. These studies suggest that: (a) Accurate self-assessments of desired changes in a problem behavior can function as reinforcers for desired changes in the problem behavior, if the accurate self-assessments have been paired with previously established reinforcers, and (b) immediate consequences produced by accurate self-assessment may be more effective as reinforcers for a problem behavior than often delayed and inconsistently delivered teacher-controlled consequences.

Can effective self-assessment be maintained in the absence of contrived reinforcers? Turkewitz et. al. (1975) systematically faded back-up reinforcers for the children's self-assessment. Eventually the children's self-administered points were no longer exchangeable for prizes. The children's average number of disruptive
behaviors remained lower than their baseline average, but higher than phases in which points were exchangeable for prizes. However, not all external consequences for effective self-assessment were eliminated. Experimenters continued to provide feedback to the children on the accuracy of their self-assessments. Bolstead and Johnson (1972) asked one group of children who had previously produced points and prizes for self-assessed decreases in disruptive behavior to continue self-assessing, even though their behaviors could no longer produce points and prizes. Although the children's average rate of disruptive behavior increased (from approximately .25 to .45 behaviors per minute), the children's rate of disruptive behavior was maintained at levels much lower than its original baseline rate (1.25 behaviors per minute). Seymour and Stokes (1976) found that when tokens were no longer available for accurately self-assessing high percentages of work behavior, three adolescent girls continued to accurately self-assess and maintain high percentages of work behavior. However, the therapist continued to praise the girls' accurate self-assessments of high percentages of work behavior.

Three of the previously cited studies (Bolstead & Johnson, 1972;
Seymour & Stokes, 1975; Turkewitz et al., 1975) attempted to
demonstrate that effective self-assessment can be maintained in
the absence of contrived reinforcement. However, in two of the
these studies, experimenters continued to provide feedback and
praise for accurate self-assessments of desired changes in a
problem behavior. Although the data provided by Seymour and Stokes
(1975) and Turkewitz et al. (1975) suggest that effective
self-assessment can be maintained when self-assessment no longer
produces tokens and prizes, these data do not demonstrate that
effective self-assessment can be maintained in the absence of
contrived reinforcement. The experimenters continued to make
contrived social consequences contingent upon effective
self-assessment. No attempts were made to control for the possible
reinforcing effects of experimenter feedback and praise may have
acquired during the course of the study. In the third study, (Bolstead
& Johnson, 1972) neither prizes nor feedback were provided for the
childrens' self-assessments, once the behavior-behavior relation
had been established with these contrived reinforcers. Although the
childrens' disruptive behavior increased when their
self-assessments could no longer produce points and prizes, the
children who continued to self-assess maintained rates of disruptive behavior substantially lower than their previous baseline rates.

Some studies suggest that effective self-assessment must be initially established by contrived changes in the external environment (Turkewitz et al. 1975; Ballard & Glynn, 1975). Accurate and effective self-assessment of desired changes in problem behavior has been established by making contrived changes in environmental events, such as praise or tokens exchangeable for prizes, contingent upon the self-assessment relation. Once established, self-assessing may partially maintain desired changes in a problem behavior, even when the self-assessment relation no longer produces changes in the external environment other than self-records (Bolstead & Johnson, 1972). Perhaps self-records can acquire reinforcing or punishing effects as a result of their pairing with externally controlled reinforcing events during the subjects' training history.

**Self-Reinforcement and Self-Punishment**

*Self-reinforcement* is defined by the applied researchers as the "self-administration of contingent rewards," while *self-punishment*...
is defined as "involving self-administered aversive stimulation" (O'Leary & Dubey, pp. 455-456). Self-determined reward and response cost token programs have been shown to maintain appropriate classroom social behavior (Kaufman & O'Leary, 1972), to increase the number of workbook pages completed (Humphrey, Karoly, & Kirschenbaum, 1978), to decrease disruptive behavior (Bostead & Johnston, 1972; Turkewitz et al., 1975), and to increase the number of sentences, action, and describing words children write (Ballard & Glynn, 1975).

Several studies have demonstrated that effective self-assessment may be maintained by self-administration of points or tokens. Subjects have been taught to self-administer reinforcing consequences contingent upon self-assessments of a desired change in problem behaviors. Effective self-assessment was maintained by self-administered points, when these points were exchangeable for various types of back-up reinforcers (Bolstead & Johnson, 1972; Turkewitz et al., 1975; Ballard & Glynn, 1975).

For example, Bolstead and Johnson (1972) demonstrated that once effective student self-assessment of disruptive behavior is established by teacher administered points, the behavior-behavior
relation can be maintained by self-administered point deliveries. The point deliveries were determined solely by the subjects' own self-assessments. The self-administered point deliveries maintained desired decreases in the childrens' disruptive behavior when points were exchangeable for previously established reinforcers such as prizes. The self-regulation procedure (self-assessment plus self-administered point delivery) was slightly more effective than an external regulation procedure (teacher assessment plus teacher administered point delivery). However, the difference between the self-regulation and external regulation procedures was not statistically significant.

Turkewitz et. al. (1975) obtained the similar results: (a) Teacher assessment and administration of points contingent upon decreases in disruptive behavior were more effective in decreasing disruptive behavior than self-assessment alone; (b) self-assessment plus teacher administered points produced further decreases in disruptive behavior; and (c) self-assessment plus self-administered points was about as effective as teacher assessment and point administration in maintaining disruptive behaviors at low levels. However, during the self-administration phase of the study,
experimenters continued to provide feedback to the children on the accuracy of their self-assessments.

In a third study, Ballard and Glynn (1975) allowed children to self-administer points contingent solely upon self-assessments of their writing performance. No initial teacher assessment and teacher-administered point delivery for increases in writing or effective self-assessment were provided. The children effectively self-assessed when they were allowed to self-administer points contingent upon assessments of increases in their writing performance. The number of sentences written by the children more than doubled from the number written when the children self-assessed but could not self-administer points for their writing. Children's self-assessments remained reasonably accurate even though the teacher did not provide consequences for inaccurate self-assessments. Perhaps the children had histories of reinforcement for correspondences between their actions and their subsequent reports of those actions, sometimes called truth-telling (Israel, 1978).

Note that applied definitions of self-reinforcement and self-punishment procedures do not specify that self-administered
consequences must immediately follow the problem behavior. Therefore these procedures, as defined, are not technically reinforcement or punishment procedures. Brigham (1980) provides an additional criticism of the term *self-reinforcement*, similar to one offered by Bandura and Mahoney (1974). Most of the studies in which self-reinforcement procedures were demonstrated to be effective do not meet an important criterion for self-reinforcement: “that the reinforcer be freely and continuously available to the subject, whether the response is emitted or not” (p. 29). Both Skinner (1953) and Catania (1975, 1976) have argued that the term *self-reinforcement* is misleading. They suggest that we must account for self-reinforcement by looking at the ultimate consequences that maintain the relationship between problem-solving and problem behavior. Under what conditions is a reinforcer freely available but only consumed following the occurrence of the problem behavior? Mahoney and Bandura (1972) established self-reinforcement in pigeons by withdrawing access to food if the subjects ate from the hopper without first pecking a key. They demonstrated that self-reinforcement was actually a behavior-behavior chain, itself established and maintained by an
externally controlled reinforcing consequence, access to food.

Reviewers of the applied research on problem-solving have noted the importance of external controls in the establishment and maintenance of the behavior-behavior relations in a problem-solving process. In their 1979 literature review Rosenbaum and Drabman state:

Every study dealing with self-control in the classroom has included external variables prior to or concurrent with the introduction of self-control training. The presence of these external variables had led several authors... to raise questions regarding the ability of self-control strategies, especially self-reinforcement, to modify and/or maintain behavior in the absence of external influence. (p. 478)

Likewise O'Leary and Dubey (1979) conclude their review of applied studies of procedures for establishing self-control as follows:

The distinction thus made between self- and external control is not meant to imply that the use of self-control procedures and the behavior they influence can somehow exist and persist in spite of or in the absence of external contingencies... Although systematic control can and has been successfully faded, naturally
occurring events must at the very least, support the behavior change. (p. 462)

The self-reinforcement relation is itself established and maintained by reinforcing changes in the external environment.

**Self-Determined Criteria**

O'Leary and Dubey define *self-determination of criteria* as "setting one's own standards of performance" (p. 452). A performance standard is a statement that specifies the type and amount of behavior, occurring under a specified set of conditions, required to produce a specified outcome. For example, "To earn an 'A' in this unit, you must correctly work 90% of the 100 long division problems I have assigned." Performance standards are another example of of the rules described by Glenn (1987) and the contingency-specifying stimuli described by Schlinger and Blakely (1987). Performance standards describe contingent relations between behavioral and environmental events.

Applied researchers classify performance standards for a problem behavior as either *externally imposed* or *self-determined*. Externally imposed standards are performance standards for a problem behavior that are stated by someone other than the
individual with that problem behavior. Teachers often state
to performance standards for their students' problem behaviors.

Self-determined standards are performance standards for a problem
behavior that are stated by the individual with that problem
behavior. For example, a student who has weak study behavior might
say: "My task for today is to read the next 100 pages in my textbook
and to write study questions for each of the objectives addressed by
the text."

Can stating a performance standard affect the problem behavior
specified in that standard? A number of applied studies have
examined the effects of stating performance standards on various
problem behaviors. The following conclusions can be drawn from the
applied literature:

1. **Effects of standard-setting as the sole intervention.** In the
   absence of reinforcement procedures, neither self-determined nor
   externally-imposed standard-setting has been demonstrated to
   affect problem behavior (Bandura & Perlof, 1967; Sagotsky, et al.,
   1978). "When criterion setting is the sole intervention, children in
   laboratory and applied settings perform no better than control
   children" (O'Leary & Dubey, 1979).
2. Effects of standard-setting combined with reinforcement procedures. The author found no studies comparing the effects on problem behavior of standard-setting combined with reinforcement to the effects of reinforcement procedures alone. However, the effects of combining different types of standards with reinforcement procedures have been evaluated. When lenient standard-setting plus reinforcement has been compared to stringent standard-setting plus reinforcement, stringent standard-setting has produced greater changes in problem behavior. For example, Brownell, Coletti, Ersnek-Herschfield, and Wilson (1977) found that the mean number of correctly worked math problems and number of minutes in the task setting was greater when reinforcement procedures were combined with a stringent standard-setting, than when reinforcement procedures were combined with lenient standard-setting. Externally-imposed and self-determined standard-setting were equally effective in changing problem behavior.

3. Comparing self-determined and externally-imposed performance standards. When combined with reinforcement procedures, self-determined and externally-imposed standards are
equally effective in changing a problem behavior, according to most applied studies (Bandura & Perloff, 1967; Felixbrod & O'Leary, 1973; 1974; Brownell et al, 1977). However, an early study by Lovitt and Curtis (1969) found that a combination of self-determined standard-setting plus reinforcement was more effective than externally-imposed criteria plus reinforcement. Interestingly, the Lovitt and Curtis study, unlike the others, employed a single-subject, repeated measures, reversal design. Most of the applied research in the area of problem-solving has employed a groups comparison design.

4. Comparing self-determined and externally imposed standards when reinforcement procedures are discontinued. Three studies have compared the extinction performance of subjects with externally-imposed standards to that of subjects with self-determined standards. In one study, subjects with self-determined standards completed a statistically significant greater number of math problems than subjects with externally imposed standards. However, the subjects' extinction performance was observed for only two sessions (Brownell et al., 1977). In a similar study, Felixbrod and O'Leary (1974) found no statistically
significant differences between performances of subjects with externally-imposed standards and subjects with self-determined standards. In a third study, (Weiner & Dubanowski, 1975) a group with self-determined standards outperformed a group with externally-imposed standards during the extinction phase of a ball-dropping task. When the performance standard was stringent, the group with self-determined standards had a higher number of on-task responses during extinction and their responding continued longer than the responding of the group with externally-imposed standards. However, the subjects' extinction performance was only observed for one session.

In summary, self-determined standard-setting has not been demonstrated to function as problem-solving behavior, unless it has been first established as part of a behavior-behavior chain that produces reinforcing changes in problem situations; reinforcement procedures are necessary to establish the behavior-behavior chain. Stating a performance standard and behaving in accordance with that standard is another example of a correspondence between saying and doing. Israel (1978) demonstrated that such behavior-behavior relations can be established by reinforcing correspondences between
saying and doing.

Some studies suggest that self-determined standard-setting may be more effective in maintaining a problem behavior during extinction than externally-imposed standard-setting. However, data on the maintenance of problem behaviors by self-determined standard-setting are inconclusive. Self-determined standard-setting might maintain problem behaviors in the absence of contrived reinforcement, if the behavior-behavior chain continues to produce reinforcing effects in the natural environment. For example, a problem-solver may make a "To-do" list, and that list may make the problem behaviors on the list more likely to occur, even though no one delivers contrived reinforcers for the problem-solving chain. Reinforcement procedures are not necessary to maintain list-making and list-following behaviors, because the behavior-behavior chain produces effective changes in the natural environment.

**Self-instruction**

O'Leary and Dubey (1979) define self-instructions as "verbal statements to oneself which prompt, direct, or maintain behavior" (p. 450), while Rosenbaum and Drabman (1979) define
self-instruction training as "training in which individuals are taught
to make suggestions to themselves to guide their own behavior in a
manner similar to being guided by another individual" (p. 476).

Applied as well as basic analysts have defined the term
self-instruction functionally, according to its effects upon a
problem behavior (Vaughan, M.E., 1985). However, such a definition
can be misleading, as self-instructions may or may not affect a
problem behavior. For example, although Bornstein and Quevillon
(1976) found a self-instruction procedure to be effective in
increasing on-task behavior, Friedling and O'Leary, (1979) failed to
replicate that study.

In their review of the self-instruction literature, O'Leary and
Dubey note four factors that determine whether a self-instruction
procedure will be effective: (a) Subjects must actually emit the
self-instruction behavior (Harting & Kanfer, 1973); (b) subjects
must emit the problem behavior with facility. In other words, a
weak problem behavior must be topographically correct when it does
occur (Hilga, Tharp, & Calkins, 1978); (c) a history of reinforcement
for following one's own instructions should be provided by the
experimenter (Israel, 1978; Burron & Butcher, 1978); and (d) the
self-instructions should relate to the problem behavior (Mischel & Patterson, 1976).

Several studies have clearly demonstrated that self-instruction procedures can be effective when properly implemented. Bem (1967) gave young children the following task: to produce a reinforcer a child was required to press a lever a number of times equaling the number of lights previously presented to the child but now absent. The child could not perform this task accurately until the experimenter had explicitly reinforced the following self-instruction relation: (a) counting the number of lights presented ("1,2,3"), (b) repeating that count during the interval between light offset and the opportunity to lever press ("1,2,3") and (c) pressing a lever the number of times corresponding to the total number of lights counted. Once the experimenter had established the self-instruction chain, the counting behavior appeared to produce discriminative stimuli that increased the children's accuracy on the lever pressing task. Grimm et al. (1973) taught students textual and counting behaviors which subsequently increased their accuracy on a task requiring them to circle the number of objects corresponding to a written number. Gettinger (1985) taught students to circle the
part of each word they had misspelled saying "This is the part of the word I need to remember" a self-instruction that produced increased spelling accuracy.

Applied analysts of problem-solving often do not attempt to identify the defective controls over the problem behavior. In the applied literature no distinction is made between motivative and discriminative types of problem-solving. Procedures are usually labeled as self-control procedures whether they produce problem-solving behaviors that affect motivative or discriminative variables for a problem behavior. A functional analysis of the controls over problem behaviors would help applied researchers to design effective procedures to establish problem-solving behaviors. The procedural terminology adopted by applied analysts of problem-solving does not lend itself to either a functional analysis of the controls over a problem behavior or a functional description of the problem-solving processes to be produced by the applied researcher. A specification of the problem-solving process to be procedurally produced would serve as a standard for the evaluation and design of effective procedures. For example, effective self-instruction and self-determined criteria procedures would
presumably train problem-solving behaviors that produce
discriminative stimuli or alter the function of other controlling
variables for a problem behavior with defective discriminative or
motivative controls. Effective self-assessment,
self-reinforcement, and self-punishment procedures would train
problem-solving behaviors that produce reinforcing or punishing
postcedent events for a problem behavior with defective
motivative controls. Perhaps correctly implemented procedures fail
because they have not included the steps necessary to establish
behaviors as problem-solving behaviors for a targeted problem
behavior. A problem-solving procedure may not have included the
steps necessary to establish instructing, standard-setting, or
assessing as problem-solving behaviors for a targeted problem
behavior. The missing components of an ineffective procedure might
include correspondence training (Israel, 1978; Burron & Butcher,
1978), pairing assessments with already established reinforcers
(Bornstein & Quevillon, 1976), or arranging reinforcers that will
maintain the problem-solving chain. (Baer et al, 1981).

Adopting a Common Terminology

Two different terminologies have evolved in the behaviorological
analysis of problem-solving: a procedural terminology, adopted by the applied empirical analysts and a process terminology, adopted by the theoretical and basic empirical analysts. Theoretical analysts classify problem-solving according to the type of controlling variables that are defective for the problem behavior. A problem behavior with defective motivational controls is a self-control problem, while a problem behavior with defective discriminative controls is a thinking problem (Skinner, 1953, 1984). Basic analysts tend to classify problem-solving according to the functional properties of the problem-solving behavior in the problem-solving process. Behaviors which provide discriminative stimuli for a problem behavior are labeled as mediating, precurrent, or self-instructional, while behaviors that preclude reinforcing consequences for a problem behavior are called commitment responses (Laties et al, 1969; Parsons et al, 1981; Vaughan, 1985; Rachlin & Green, 1972). Applied analysts classify problem-solving according to the type of procedures designed to produce the problem-solving relation: self-instruction, self-determined criteria, self-assessment, self-reinforcement, and self-punishment. A useful terminology for the analysis of problem-solving would
include both procedure and process descriptions of the problem-solving behaviors. Adoption of a process terminology by applied analysts would allow them to do a functional analysis of the controls over a targeted problem behavior. Such an analysis would allow applied researchers to tailor their procedures to the type of problem behavior targeted for change. For example, changing a discriminative problem behavior requires procedures that produce discriminative problem-solving behaviors, while changing a motivative problem behavior requires procedures that produce motivative problem-solving behaviors. Adoption of procedure terminology by basic and theoretical researchers would allow them to maintain a useful distinction between problem-solving procedures and processes. Analyses of problem-solving are currently being pursued by researchers working in three different behaviorological domains: theoretical, basic empirical, and applied empirical. If a common termininology for the behaviorological analysis of problem-solving were adopted, research from each domain would be more accessible to those working in the other two domains.
Needed: A General Term For The Behavior-Behavior/Environment Relation

A variety of terms have been adopted by behaviorologists working with the different types of behavior-behavior/environment relations: procedural terms such as, *self-instruction*, *self-determined criterion setting*, *self-determined contingencies*, *self-observation*, *self-assessment*, *self-recording*, *self-evaluation*, *self-reinforcement*, and *self-punishment* (O'Leary & Dubey, 1979; Rosenbaum & Drabman, 1979) and process terms such as, *self-control* (Skinner, 1953; Goldiamond, 1965; Rachlin & Green, 1972), *self-management* (Skinner, 1953), *self-directed behavior* (Watson & Tharp, 1972), *thinking* (Skinner, 1953), *mediating behavior* (Skinner & Ferster, 1957; Laties et al., 1965), *precurent operant* (Skinner, 1966; Parsons et al., 1981), and *problem-solving* (Skinner, 1953; Grimm, et al., 1972). Which of these, if any, would be best suited as a general term for the different types of behavior-behavior/environment relation?

A general term for the behavior-behavior/environment relation must satisfy several criteria. (a) The term should describe a behavior-behavior/environment relation, not the intervention
procedures designed to establish that relation. (b) The term should have an etymological history consistent with a behaviorological definition of a behavior-behavior/environment relation. (c) The term should describe a complete behavior-behavior/environment relation, not just some part of that relation. (d) The term should apply to the different types of behavior-behavior/environment relations of interest to behaviorologists. For example, the term should describe both discriminative and motivative types of behavior-behavior/environment relations, and the term should describe relations in which the problem behavior is either preceded or followed by a problem-solving behavior.

Procedural Terms

Procedural terms, such as *self instruction*, *self-determined criteria self-assessment*, *self-reinforcement*, and *self-punishment*, describe intervention procedures designed to establish new behavior-behavior/environment relations, rather than those relations themselves. Thus, procedural terms are inadequate as general terms for the various types of behavior-behavior/environment relations.
Process Terms

As defined by behaviorologists, terms such as: *self-control*, *self-management*, *self-directed behavior*, *thinking*, *mediating behavior*, *precurent operant*, and *problem-solving*, are process terms. Each describes a behavior-behavior/environment relation, a behavior-behavior relation, or a behavior that is functionally related to one or more behavioral or environmental events.

**Terms with the word self.** Process terms, such as *self-control*, *self-management*, or *self-directed behavior*, are unsuitable as behaviorological terms, because they include the word *self*. The word *self* has a rather disreputable history: The self is most commonly used as a hypothetical cause of action. So long as external variables go unnoticed or ignored, their function is assigned to an originating agent within the organism (Skinner, 1953, p. 283).

The word *self* implies that the individual is the locus of control rather than the environment (Brigham, 1980), a definition inconsistent with a behaviorological approach to the study of behavior. Of course the term *self* does not have to be defined as an originating agent. Skinner (1953) has defined *self* as "...simply a device for representing a functionally unified system of responses"
However, as Hineline (1984) has argued, traditional terms such as *self*, even if defined operationally, tend to occasion nonbehaviorological explanations of behavior.

*Thinking.* The term *thinking* also has an unfortunate etymological history. *The American College Dictionary* (1967) defines *thinking* as "to form or conceive (a thought, etc.) in the mind" (p. 1259). Thus the term *thinking*, like terms that include the word *self*, has an etymological history inconsistent with a behaviorological definition of *thinking* as a type of behavior-behavior/environment relation.

*Mediating behavior and precurrent operant.* Mediating behavior and precurrent operant are terms describing one or more parts of a behavior-behavior/environment relation, not the entire relation. *Mediating behavior* is a term for one or more of the behaviors involved in a behavior-behavior/environment relation. *Precurrent operant* is a term for a behavior-behavior relation, itself only a part of the larger behavior-behavior/environment relation. The complete behavior-behavior/environment relation is composed of two operants, one precurrent and the other current. A precurrent operant is a behavior that makes a subsequent operant (the current
operant) more effective with respect to some environmental event. The precurrent operant is reinforced by the changes it produces in the current operant. Together the precurrent and the current operant comprise a complete behavior-behavior/environment relation.

The precurrent operant only describes one of the possible types of behavior-behavior relations that can produce reinforcing environmental changes. The precurrent operant is the type of behavior-behavior relation in which a problem-solving behavior precedes or is precurrent to a problem behavior, for example, a relation in which an instructing behavior alters the probability of a problem behavior. The term precurrent excludes the type of behavior-behavior relation in which a problem-solving behavior follows a problem behavior, for example, a relation in which an assessing behavior follows a problem behavior and alters the subsequent probability of that problem behavior, so that the behavior produces reinforcing changes in a problem situation.

Problem-solving. According to Webster's New 20th Century Dictionary Unabridged (1977), the etymological root of the term problem is the Greek "proballein" which translates "to throw
The dictionary offers two definitions of the term *problem*: (a) "a question proposed for solution or consideration" and (b) "a question, matter, situation, or person that is perplexing or difficult". Such a definition is consistent with a behavioriological definition of a problem as an environmental obstacle with respect to some behavior, specifically a situation in which a behavior that could produce reinforcers is not likely to occur, or a situation in which a behavior that could produce punishers is likely to occur.

Problem-solving is traditionally defined as a process (Webster's New 20th Century Dictionary Unabridged, p. 1728), a process involving changes in a problem situation until that situation ceases to be a problem. This traditional definition is consistent with a behavioriological definition of problem-solving as a behavior-behavior/environment relation. For example, Skinner (1969) defines problem-solving as follows:

The behavior observed when a man solves a problem [produces changes in an environmental obstacle to behavior] is distinguished by the fact that it changes another part of his behavior and is reinforced and strengthened when it does so.
The term *problem-solving*, as defined by both the lay person and the behaviorologist, describes a complete behavior-behavior/environment relation, not just a part of one.

The term *problem-solving*, whether defined by the behaviorological or lay community (Skinner, 1969; *Webster's*, 1977), is general enough to include both motivative and discriminative types of behavior-behavior/environment relations. A problem, whether described as a difficult situation or as an environmental obstacle to behavior, is a maladaptive behavior/environment relation involving defective motivative or discriminative controls. The term problem-solving can therefore apply to any behavior-behavior relation that produces reinforcing changes in either motivative or discriminative types of problems.

The term *problem-solving* can describe relations in which the problem-solving behavior either precedes or follows the problem behavior. The term *problem-solving*, unlike the term *precurrent*, does not imply a behavior-behavior relation in which a problem-solving behavior must precede the problem behavior.

The term *problem-solving* is, at present, the best general term
for the different types of behavior-behavior/environment relations of interest to behaviorologists. Problem-solving is a term that describes the complete behavior-behavior/environment relation. The term can apply to the various types of behavior-behavior/environment relations, discriminative, motiveative, and relations in which the problem-solving behavior either precedes or follows the problem behavior. Finally, problem-solving is a term that has an etymological history consistent with its behaviorological definition as a behavior-behavior/environment relation.
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CHAPTER V

TEACHING PROBLEM-SOLVING: BEHAVIOROLOGICAL APPLICATIONS

Students have problems. They behave disruptively in class, when such behavior eventually leads to teacher reprimands and perhaps expulsion. They fail to do their assignments, when doing their assignments could eventually lead to better grades. They call the written number "6" a "nine" and the written number "9" a "six," when doing so will produce punishing teacher reprimands. They cannot circle the number of shapes that corresponds to a written number, when doing so could produce reinforcing teacher praise.

Teachers solve student problems. They alter student environments so that students are less likely to behave disruptively, by allowing students to earn tokens for appropriate behavior and exchange those tokens for prizes. They provide study halls in which early dismissal depends upon study behavior, so that students are more likely to complete their assigned work. They state rules such as "if the stem goes up, its a six; if the stem goes down, its a nine," so that students are less likely to call a "6" a
“nine” or a “9” a “six.” They name written numbers and count the number of shapes that correspond to those numbers, so that students can circle the number of shapes that corresponds to each written number.

But students must eventually learn to solve their own problems. Students must learn to arrange their environments so that, without teacher assistance, they are: (a) less likely to behave disruptively, (b) more likely to do their assigned work, (c) less likely to misname the written numbers “6” and “9,” and (d) more likely to circle the number of shapes that corresponds to a written number. Teachers must teach their students motivative and discriminative problem-solving behaviors.

Behaviorologists have developed techniques for teaching motivative problem-solving behaviors. The procedures described in the previous chapter can establish self-recording as a motivative problem-solving behavior. Children who record the number of assigned workbook pages they have completed are more likely to do their assigned work; children who record the number of disruptive behaviors they have emitted are less likely to behave disruptively.

Behaviorologists have developed techniques for teaching
discriminative problem-solving behaviors. The techniques described in the previous chapter can establish self-instructing as discriminative problem-solving behavior, so that stating simple rules such as "if the stem goes up, it's a six; if the stem goes down, it's a nine," makes a student less likely to call a "6" a "nine" and a "9" a "six," or naming a written number and counting the number of shapes that corresponds to that number make a student more likely to circle the number of shapes that correspond to that written number.

Teaching students to produce discriminative and motiveive stimuli for their problem behaviors should always be included as the final step in any instructional intervention. Teaching discriminative and motiveive problem-solving behavior is a technique that will facilitate the generalization of other newly acquired student behavior to the post-instructional setting. As Vargas and Fraley (1974) have stated, the ultimate teacher goal is to get the student to behave more effectively with respect to some subject matter, without teacher assistance.

Rule-Stating: A Problem-Solving Behavior

Students have been taught to self-instruct, self-assess, and to
set their own performance standards, behaviors that can function as discriminative or motivative problem-solving behaviors for a variety of problem behaviors. But with the exception of M.E. Vaughan (1985), behaviorologists have yet to develop techniques to teach more complex discriminative problem-solving behaviors, problem-solving behaviors such as formulating and stating complex rules for the solution of problems that require a sequence of changes in problem situations. Recently, however, behaviorologists have begun to study the ways in which rule-stating behaviors can affect problem behaviors (Baron, Kaufman, & Stauber, 1969; Bentall, R.P., Lowe, C.F., & Beasty, A., 1985; Catania, Mathews, & Shimoff, 1982; Galizio, 1979; Kaufman, Baron, & Kopp, 1966; Mathews, Catania, & Shimoff, 1985; Vaughan, M.E, 1985).

A Rule Defined

A rule has been defined as a verbal contingency-specifying stimulus (Skinner, 1969; Glenn, 1987). A rule is a verbal stimulus, in that a rule is a "product" of verbal behavior. A rule is a contingency-specifying stimulus, in that it describes a contingent relationship between two or more environmental events. For example, the rule "If the stem goes up, its a six," describes a
dependent relation between three environmental events: (a) a written number with a stem that goes up, (b) naming that number as a six, and (c) the implied consequence of naming that number as six, reinforcement by members of the individual’s verbal community. If a written number has a stem that goes up, naming that number as a six will be reinforced by members of the student’s academic verbal community, especially the one called teacher. As Glenn (1987) has argued, the contingent relation described by the rule does not have to include a behavior. For example, the equation "E=MC^2" describes a contingent relationship between two nonbehavioral events, energy and mass. According to Glenn, a rule is most usefully defined independently of its effects on a problem behavior. Defining a rule independently of its effects allows us to talk about the different ways in which a rule may affect a problem behavior and to talk about rules that have no effects upon a problem behavior.

The Functional Properties of Rule-Stating Behavior

A number of basic empirical researchers have demonstrated that rule-stating can affect problem behavior (Baron, Kaufman, & Stauber, 1969; Galizio, 1979; Kaufman, Baron, & Kopp, 1966; Vaughan, M.E., 1985). For example, Kaufman et al. (1966) found that
experimenter-stated instructions can affect the rate of subject behavior:

S's given either VR, VI, or FI instructions, in addition to instructions about the response, behaved in many respects as if they had already been trained on the schedule to which the instructions referred. Thus, VR instructions induced high rates, FI instructions induced low rates, and VI instructions intermediate rates of response. (p. 246)

Kaufman et al. demonstrated that experimenter-stated instructions can affect the rate of subject behavior even when such behavior is inappropriate to the schedule actually programmed. In the cases of the VR and Response conditions, for example, extremely high rates were maintained although considerably lower rates of response would have produced an equivalent number of reinforcements. (p. 246)

When experimenter-stated instructions specify that different patterns of behavior are required to produce programmed consequences in the presence of different antecedent stimuli, those instructions can produce different rates of behavior in the presence of those antecedent stimuli (Baron et al., 1969; Galizio, 1979). For
example, when Galizio (1979) added instructional labels to the antecedent stimuli correlated with different avoidance schedules, In the case of the three subjects who had not previously shown complete discriminative control, ... the addition of instructions had major effects. Discrimination among all four components was evident within the first instruction session. (pp. 57-58)

Whether experimenter instructions affect subject behavior depends upon the consequences produced by subject behavior when it corresponds to those instructions. Galizio (1979) found that "when instruction-following led to exposure to the loss contingency, instructional control was rapidly eliminated" (p. 62). Galizio also demonstrated that accurate instructions can function as reinforcers for subject behavior. When his subjects behaved in accordance with experimenter instructions and such behavior did not result in monetary loss, the instructions functioned as reinforcers for subject observing responses.

When rules are stated by the subjects themselves rather than the experimenter, those rules may also affect subject problem behavior. M.E. Vaughan (1985) taught her subjects to describe their own behavior as they worked on a button-pressing task. When
subjects could describe the sequence of button presses required to produce programmed point increments and tones, they performed more accurately than when they could not describe that required sequence.

The basic empirical research on rule-stating suggests that rules may affect subject problem behavior, whether the rules are stated by the experimenter or by the subject. M.E. Vaughan's research suggests that complex rule-formulating and rule-stating behavior can be explicitly trained by educators, and that such behavior may function as problem-solving behavior in complex problem situations.

**Rule-Stating: An Important Part Of A Curriculum**

Rule-stating behaviors are an important part of many curricula. Rules (sometimes called procedures) specify effective ways to manipulate the environmental objects and events that comprise a subject matter. Each discipline has a set of rules or procedures designed to facilitate expert behavior with respect to its subject matter. For example, engineers have procedures for bridge-building; chemists have procedures for synthesizing and analysing chemical substances; biologists have procedures for altering the physiological processes of organisms, and behaviorologists have
procedures for producing desired behavior/environment relations.

Thus, rule-stating behaviors are usually included among the objectives defining mastery of a subject matter.

A definition is merely a rule for the correct identification of any instance of a concept class. For example, biologists define a mammal as a vertebrata: (a) whose young are nourished with milk produced by special mammary glands of the mother, (b) with a body typically covered with hair, (c) with a mandible consisting of a single pair of bones which articulate directly with the skull, (d) with three auditory ossicles in the middle ear, (e) with a cartilaginous external ear, (f) with a left aortic auricle, (g) with nonnucleated red blood cells, (h) with a great development of the cerebral cortex and (i) with young born alive after a relatively long period of gestation within the uterus of the mother (The Encyclopedia of Biological Sciences, 1961, pp. 584-585). The definition of a mammal is a rule for the correct identification of any instance of the concept class mammal. If an animal is a vertebrata and has properties a–i, it will be correct to call that animal a mammal.

Every discipline has a number of other useful rules to be taught. In English Composition a familiar spelling rule is: "i before e except
after c, or when sounded as (long) a, as in neighbor and weigh.” For words having “ie” and “ei” letter combinations, writing “i” before “e,” except when the “ie”/“ei” letter combination follows a “c,” or is sounded as a long “a,” will be evaluated as correct by the student’s verbal community.

Teaching Rule-Stating As Problem-Solving Behavior

Rule-stating may or may not affect a problem behavior. For example, we may state rules such as “Smoking causes cancer” and “High cholesterol causes heart attacks” but continue to smoke and to eat foods high in cholesterol. Teachers must not only teach rule-stating behaviors, but also ensure that rule-stating behaviors acquire functional control over the targeted problem behaviors.

To establish rule-stating as problem-solving behavior, rule-stating must be taught as part of a behavior-behavior relation, consisting of rule-stating and desired changes in a problem behavior. In addition, the behavior-behavior relation must produce reinforcing changes in a problem situation. O’Leary and Dubey’s (1979) suggestions for teaching effective self-instruction behavior apply to teaching effective rule-stating behavior. The teacher should: (a) provide the students with good rules, (b) ensure that
both the behaviors of stating and following the rule actually occur and are reinforced as a behavior-behavior chain, and (c) establish a problem-solving relation that will produce uncontrived reinforcers, so that the relation is likely to maintain in post-instructional settings.

1. Providing good rules. A good rule will apply to all instances of the class of problems to be presented. For example, the rule, "if the stem goes up, it's a six; if the stem goes down, it's a nine," is a good rule, if it allows the learner to identify any example of a written "6" or "9" correctly. An especially good rule accurately describes the natural contingencies that the problem-solver will encounter in problem situations outside the instructional setting. A rule, such as "If the stem goes up it's a curlicue," is not a good rule, because it does not describe behaviors that will be reinforced in post-instructional problem settings. The verbal community outside the instructional setting will not reinforce calling a six a "curlicue." Teaching students to state good rules will facilitate the post-instructional generalization and maintenance of new problem-solving relations, because the rules accurately describe behaviors that will produce reinforcers in post-instructional settings.
problem situations.

2. Building the problem-solving relation. To establish effective rule-stating behavior, the teacher should first shape the desired changes in a problem behavior. For example, the student must correctly pronounce the written number "6" before rule-stating will affect the correct naming of the written number "6." Secondly, the teacher should prompt and reinforce accurate rule-stating. For example, the teacher should prompt and reinforce accurately stating the rule, "If the stem goes up, it's a six; if the stem goes down, it's a nine," when the teacher has presented the written number "6" and asked "What number?" Thirdly, the teacher should reinforce a correspondence between accurate rule-stating and desired changes in a problem behavior. For example, if the student correctly names a written number "6" after stating the rule "if the stem goes up, it's a six," the teacher should make reinforcing consequences contingent upon that correspondence between rule-stating and rule-following behavior.

3. Maintaining the problem-solving relation. Once an effective rule-stating and rule-following relation has been established, it must be maintained by the reinforcing consequences it produces in
the post-instructional setting. Thus the teacher should ensure that
the new behavior-behavior/environment relation effectively
produces uncontrived reinforcing consequences that are likely to
maintain that relation in the absence of the teacher. For example,
stating the rule, "If the stem goes up, it's a six; if it goes down, it's a
nine" in the presence of a "6," will usually produce reinforcing
consequences from members of the student's verbal community,
when they have asked the student to read an address that contains
the written number "6."

To transfer control of the new rule-stating and rule-following
relation from teacher-delivered prompts and reinforcers to
naturally-occurring changes in the problem situation, the teacher
should systematically fade the contrived prompts and reinforcers
used to establish the relation, as the naturally reinforcing
consequences produced by the relation began to make that relation
more likely to occur in similar problem situations.

If the teacher follows the three steps listed above, the student
will not only have been taught to state a rule correctly, but also to
follow that rule correctly. Effective rule-stating is a useful type of
problem-solving behavior which can be explicitly trained by
Algorithm-Defining Behavior

Algorithm Defined

Although Skinner never explicitly defines the term *algorithm*, it does appear several times in his theoretical writings on problem-solving (1957, 1966, 1968, 1984). Skinner (1966) has described the algorithmic problem-solver as a "student who has learned to recognize various kinds of problems and apply relevant techniques" (p. 21). Skinner implies that an algorithm is a type of rule or instruction when he describes the algorithmic problem-solver's behavior as "nothing more than specified topographies evoked by specified occasions" (p. 21). In his 1984 article, *An Operant Analysis of Problem-solving*, Skinner discusses the "rules in first-order (possibly algorithmic) problem-solving" (p. 586) and refers to "the algorithmic problem-solver who simply follows instructions" (p. 588).

Non-Skinnerian problem-solving theorists such as Scandura (1977) offer a definition of the term *algorithm* similar to the one implied by Skinner. Scandura defines an algorithm as a:

procedure/rule... that necessarily terminates in a finite
number of steps... a restricted type of mechanical procedure that may be applied to any problem in a given class... a fixed, finite, sequence of explicitly given operations and decision-making capabilities that are applied in order. (p.152)

Thus, in both behaviorological and cognitive problem-solving literatures, the term *algorithm* has come to refer to a rule for the solution of a specified class of problems. Scandura offers the following example of an algorithm for finding the sums of two or more 1-digit addends in a column addition problem. (See Figure 1.)

As no behaviorologist has yet offered an explicit definition of the term *algorithm*, the author suggests the following one: an algorithm may be defined as a rule that is stated as a series of instructions. Each instruction specifies some problem-solving behavior to be emitted. The instructions are stated in a fixed, finite sequence. The behaviors specified by the instructions are to occur in that same order. The rule is applicable only to a specified class of problem behaviors, for which the algorithm is named. In summary, the algorithm is a complex rule that specifies a sequence of problem-solving behaviors that will alter a specified class of problem behaviors, so that reinforcing changes are produced in a
1. Add the top two addends.
2. If there are no other addends go to step three, otherwise go to step four.
3. Write the sum.
4. Add the units digit of the obtained sum to the next addend.
5. If the sum is larger than ten, go to step six, otherwise go to step seven.
6. Add one to whatever is in the ten's place and return to step two.
7. Return to step two.

Figure 1. Algorithm for finding the sums of two or more 1 digit numbers in a column addition problem. SOURCE: Scandura (1977, p. 350).
specified class of problem situations. The algorithm, like any rule, is a verbal contingency-specifying stimulus. It specifies a contingent relation between two or more environmental events: (a) a series of problem-solving behaviors emitted in a specified order, (b) that alter a specified class of problem behaviors, so that (c) those problem behaviors produce reinforcing changes in the problem situations for which the algorithm has been named.

Restating Complex Definitions as Algorithms

Algorithms can be written for the solution of many different types of problems, both mathematical and nonmathematical. For example, concept definitions can be restated as algorithms for the solution of concept example identification problems.

To illustrate how algorithms for the solution of concept identification problems can be derived from concept definitions, we may restate the behaviorological definition of a reinforcement process, "A reinforcement process is a functional relationship between an environmental change immediately following a behavior and an increase in the rate or probability of that behavior," as an algorithm for the identification of reinforcement process examples. (See Figure 2.)
1. Is there a behavior? Name it.

2. Is there a change in the environment? Name it.

3. Does the change in the environment immediately follow the behavior?

4. Does the behavior increase in rate or probability?

5. If the answer to the all of the above questions is "yes," the item is an example of a reinforcement process.

**Figure 2.** Algorithm for the identification of reinforcement concept examples. SOURCE: Miller (1980).
Algorithms in Schematic Form

A schematic is a spatial representation of relationships between environmental events. Thus, schematics are spatial representations of rules. A concept definition is a rule for the identification of concept examples that can be represented schematically. For example, each definition of the basic behavioral processes has a unique schematic representation. (See Figure 3.)

A schematic representation of a concept's defining properties is a schematic form of the previously described algorithm for the identification of concept examples. Each property of the concept that is represented in the schematic, along with its schematic label, is an algorithmic instruction. Each label asks the problem-solver to identify the presence or absence of its concept property in a given example. (See Figure 4.) If the example is a positive example of the concept, its schematic will match the schematic of that concept's defining properties. (See Figure 5.) Any example of the basic behavioral processes: reinforcement and extinction, punishment and recovery, discriminated reinforcement, discriminated punishment, generalized reinforcement, generalized punishment, can be identified by drawing a schematic of that
<table>
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<td>decrease</td>
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</tbody>
</table>

Key: $X = \text{a behavioral or environmental event; } X_1 = \text{not } X; X_2 = \text{not } X \text{ or } X_1$

**Figure 3.** Schematic representations of the basic behavioral processes.
**Key:** $X = \text{a behavioral or environmental event.}$

**Figure 4.** Algorithm in schematic form for the identification of reinforcement examples. (The schematic labels are read from left to right as follows: (a) Is there a behavior? Name it. (b) Is there a change in the environment immediately following that behavior? Name it. (c) Does the rate or probability of the behavior increase? Draw an arrow pointing upward or downward or a horizontal slash indicating no change.)
A student raises his hand when the teacher asks a question during a class discussion. The teacher immediately calls upon that student. The student is more likely to raise his hand when the teacher asks subsequent questions.

Figure 5. Identifying a positive written example of a reinforcement process by drawing a schematic of that example and then comparing the schematic to the schematic representation of a reinforcement process.
example and then comparing that schematic to schematics of the basic behavioral processes. (See Figure 6.)

**Teaching Algorithm-Stating As Problem-Solving Behavior**

Algorithm-stating may or may not affect a problem behavior. A student may be taught to recite the instructions in an algorithm correctly, and yet the student may not behave in accordance with those instructions. In lay terms, the student has been taught to state the algorithm but not to follow it. For example, although a student might correctly recite the instructions listed in an algorithm for finding the sums of two or more 1-digit addends in a column addition problem, that student might continue to add 1-digit numbers incorrectly (not in accordance with the steps given in the algorithm and in a way that produces incorrect answers). Or a student might correctly recite the instructions in an algorithm for the correct identification of a behavioral process and yet continue to identify examples of the behavioral process incorrectly.

Teachers must not only teach algorithm-stating behavior, but also ensure that algorithm-stating acquires functional control over targeted problem behaviors.

Algorithm-stating, like other types of rule-stating, must be
Figure 6. A general frame for drawing a schematic of any example of a basic behavioral process. The example is identified as a positive example of a basic behavioral process by comparing its schematic to the schematic representations of the different basic behavioral processes. Effective algorithm-stating is a useful type of problem-solving behavior that can be explicitly trained by educators.
established as problem-solving behavior. Algorithm-stating must be made a part of a behavior-behavior relation, consisting of algorithm-stating and desired changes in a problem behavior, that in turn, produces reinforcing changes in a problem situation. Previous suggestions for teaching effective rule-stating behavior also apply to teaching effective algorithm-stating behavior. The teacher should: (a) provide the students with good algorithms, (b) ensure that both the behaviors of stating and following the algorithm actually occur and are reinforced as a behavior-behavior chain, and (c) establish a behavior-behavior relation that produces uncontrived reinforcing of the type likely to maintain that relation in post-instructional settings. If the teacher follows the three steps listed above, the student will learn not only to state algorithms correctly, but also to follow those algorithms correctly, and to continue to state and follow algorithms correctly in post-instructional settings.

Application of a Procedure for Teaching Algorithmic Problem-Solving

Data from a preliminary study suggest that a procedure implemented by the author may be effective in establishing
algorithm-stating as problem-solving behavior.

The Problem

A student had repeatedly scored below a 75% criterion level on different forms of a quiz designed to measure mastery of the first module in an introductory educational behaviorology course. To receive grade credit for having enrolled in the course, the student was required to score at or above a 75% criterion on quizzes designed to measure mastery of the nine module units in the course. Quiz items for module one asked the student to identify positive and negative written examples of behaviorological concepts such as an explanatory fiction, an explanation, and a hypothetical construct.

Each form of a module one quiz contained 20 multiple choice items. A typical item presented a positive or negative example of a behaviorological concept along with four possible concept names for that item. The student was asked to mark the letter of the correct concept name for each example. (See Figure 7 for an example of a typical test item from a module one quiz.)

Subject History

The subject was a male undergraduate, enrolled in an educational
QUESTION NO. 112

From the following statements, select the explanatory fiction.

1. Steve looks at girls because he finds them attractive.
2. Sally works late at night because when the work is not done, she can't leave town.
3. Don studies psychotherapy because he has many personal problems himself.
4. Marj cooks good food because when she does everyone eats a lot.

Figure 7. A typical module one quiz item.
behaviorology course at West Virginia University. He was required to complete the course to earn his teaching degree. After each of his attempts to pass the module one quiz, the student had received tutoring from one of a number of different course instructors, including the author. Some or all of the following tutoring techniques were implemented by the different tutors: (a) The tutor presented concept definitions and examples, i.e.; the tutor stated the definition of an explanatory fiction and provided positive examples of an explanatory fiction, such as "He's smart because he has a lot of intelligence," and negative examples of an explanatory fiction, such as "He makes high grades on tests because he had good teachers"; (b) the tutor stated algorithms designed to help the student identify a specific concept example (see Figure 8); (c) the tutor asked general questions, such as "What is the principle that applies to this example?"; (d) the tutor applied prompting, reinforcement, and correction procedures to strengthen correct student answers to the tutor's questions, i.e.; the tutor asked a series of algorithmic questions designed to help the student identify a concept example; the tutor prompted and praised the student's correct answers to each question; after the student had correctly answered each of the
1. What are the two events which are said to be a cause and effect?
2. Is one event just another name for the other?
3. Is the evidence for one event the same as the evidence for the other?
4. If the only way you know that one event happens is by looking at the other event, then the two events are the same.

Figure 8. Questions to identify examples of explanatory fictions (Vargas, J.S., 1977).
tutor's questions about an example, the student was asked to identify that example; if the student could not identify that example correctly, the tutor pointed to the relevant parts of the example and repeated the previous tutor questions and student answers; the tutor praised correct identifications of each example, when they occurred; (e) finally, the tutor attempted to fade prompting, reinforcement, and correction procedures, so that the student could correctly identify concept examples without tutor assistance, i.e.; the student could correctly name a statement as a positive or negative example of an explanatory fiction, without tutor assistance.

Construction of the Measurement Instrument

A number of different quiz forms for each module in the course had been constructed by randomly drawing quiz items from a pool of items containing six times the number needed for any one form of the quiz. Thus, different forms of the quiz for each module were designed to contain an equal number of novel but equivalent items to test the behavioral objectives for that unit (Fraley & Vargas, 1976).

Dependent Variables

Number, percentage, and frequency measures of the subject's correct and incorrect responses were collected from the subject's
performance on each quiz form administered for a given module.

Results of Traditional Tutoring Techniques

Traditional tutoring techniques had no apparent effect upon either subject accuracy or frequency of correct responding to module one quiz items. Subject accuracy scores remained within a range of 50 to 60% correct across administrations of the different quiz forms. The subject’s frequency of correct responding remained within a range of .37 and .50 correct responses per minute, with no detectable trend toward mastery of the concept identification problems in module one. (See the baseline portions of the accuracy and frequency graphs in Figure 9.)

Teaching Algorithm—Stating Behavior

The author designed algorithms for each of the subject’s concept identification problems in the first four modules of the course. Each algorithm was formulated by restating a concept definition as a series of instructions. Each instruction asked whether a defining property of a concept was present or absent in an example. Algorithms were presented in either schematic or nonschematic form, depending upon the type of concept identification problem to be solved.
Figure 9. Module one percentage correct/incorrect and frequency correct/incorrect by Julian day.
Using prompting, reinforcement, and correction procedures, the author taught the subject to recite each algorithm correctly. For example, the author taught the subject to state an algorithm for the identification of explanatory fiction and explanation examples (see Figure 10) by: (a) prompting "What is the first step, second step, etc.?," (b) repeating parts of each instruction as necessary, and (c) giving immediate feedback on the correctness of the student's instruction-stating.

Establishing Algorithm-Stating Behavior as Problem-Solving Behavior

To establish algorithm-stating as problem-solving behavior, the author implemented the following procedure: (a) A series of written positive and negative examples were presented for each behaviorological concept to be identified. The examples were similar to the ones presented on the quiz; (b) to establish the algorithmic problem-solving relation, the author applied prompting, reinforcement, and correction procedures so that, in the presence of concept examples, the subject correctly stated the instructions in the algorithm, emitted the behaviors specified in the instructions, and then correctly identified the concept example; (c) the author
1. What are the two events described?
2. Is one event said to cause the other?
3. Are the two events described the same or different? Can you observe one event separately from the other? Do the two events take place in different times or places?
4. If you can only observe one event then the two events are the same. The example is an explanatory fiction.
5. If you can observe two different events and the two events are described differently, then the example is an explanation.

Figure 10. Algorithm for identifying examples of explanatory fictions and explanations.
then faded prompting, reinforcement, and correction procedures so that the subject correctly stated the instructions in the algorithm, correctly followed those instructions, and correctly identified the concept examples without author assistance.

For example, (a) the author presented a statement that was either an explanatory fiction or an explanation and said, "What is the first question you should ask?"; (b) if the subject correctly recited the first instruction in the algorithm for identifying examples of explanatory fictions and explanations, i.e., "What are the two events described?," the author that behavior and then said, "Answer your question."; if the subject correctly answered the question, the author praised that correct answer and then asked, "What is the next question?"; once the subject had correctly asked and answered each question in the algorithm, the author next asked, "What example is this?"; if the subject could not identify the example correctly, the author prompted the correct example name by restating the subject's previous questions and answers; when the subject correctly identified the example as an explanation or explanatory fiction, the author praised that behavior; (c) finally, the author began to fade both prompting and reinforcement procedures; the
author gradually asked fewer questions and praised fewer of the subject's correct problem-solving behaviors, so that aspects of the problem situation itself, such as the type of problem presented, the instructions stated by the subject, and the signs of progress towards the solution of a problem could begin to acquire discriminative and motivative control over the subject's problem-solving behaviors.

Both Miller and Weaver\textsuperscript{19} (1975) and Engelmann and Carnine\textsuperscript{20} (1982) include a similar series of questions in their procedures for training concept identification behavior. However, the questions are presented by either text or teacher, not by the student. The student is not explicitly trained to ask questions, but only to answer them. Without self-questioning training, student concept identification behavior may not generalize from training to testing settings.

**Experimental Designs**

The algorithmic problem-solving training procedure was applied to subject concept identification behavior in four consecutive modules of the educational behaviorology course. Concepts to be identified included: explanations and explanatory fictions, parts of the three-term contingency, types of graphs (count, rate,
cumulative, percent), some of the basic behavioral processes (reinforcement & extinction, punishment), and some associated behavior change procedures (reinforcement, extinction, and punishment). Treatment was introduced according to variations of three different experimental designs: repeated comparison, interrupted time series with multiple replications, and multiple baseline.

**Repeated Comparison Design.** The algorithmic problem-solving training procedure was applied to the problem behaviors in the four module units according to a repeated comparison design. In a repeated comparison design, a series of baseline ("A") measures followed by intervention ("B") measures is consecutively taken for different classes of subject behaviors. Miller (1980) provides a description of the comparison or "AB" design. The design can also be represented schematically. (See Figure 11.)

The author collected two to five baseline measures of the subject's quiz performance on each module before implementing the algorithmic problem-solving training procedure in that module. When the subject's performance on the module's quizzes reached an accuracy criterion of 75% (the course mastery criterion), tests and
Figure 11. The repeated comparison design.
interventions were discontinued for that module. Baseline testing was then begun for the next module.

Prior to each quiz administration, the author implemented one of the following baseline or treatment procedures; procedures were administered in the order indicated for each module (see Table 1):

(a) Baseline 1 procedure was implemented for modules one, two, three, and four; during Baseline 1 no tutoring was given; however, the subject was sometimes reminded to read and study the textual materials for the unit; (b) Baseline 2 procedure was implemented for modules one and two; during Baseline 2 traditional tutoring was given; the subject was not trained to ask the algorithmic questions; (c) Baseline 3 procedure was implemented for modules one, two, and four; during Baseline 3 algorithmic problem-solving training procedures were implemented; the subject was taught to ask and answer the algorithmic questions correctly, but with examples different from those presented on the quiz forms; (d) once the different baseline procedures had been tried for a module, the treatment procedure was implemented; treatment combined the previously tried algorithmic problem-solving procedure with examples similar to those presented on the quiz forms.
Table 1

Sequence of Baseline and Treatment Procedures Implemented in Each Module

<table>
<thead>
<tr>
<th>Module</th>
<th>Baseline 1</th>
<th>Baseline 2</th>
<th>Baseline 3</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>x</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>x</td>
<td>x</td>
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<td>3</td>
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<td>X</td>
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<tr>
<td>4</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Approximately three months after the subject had initially mastered modules one, two, and three, the subject was again tested on those modules. As subject performance had dropped below the course 75% mastery criterion, algorithmic problem-solving training was once again implemented until the subject was scoring at or above 75% accuracy. Thus, the author's treatment design included features of an interrupted time series design with multiple replications as described by Cook and Campbell (1979). A short time series was interrupted by a treatment intervention. The intervention was withdrawn for a period of three months and then reintroduced.

Multiple baseline design. For the problem behaviors in module three, the treatment was introduced according to a multiple baseline design (Miller, 1980). Algorithmic problem-solving training was given for one class of problem behaviors in the module, while baseline conditions remained in effect for other problem behaviors in the module. Thus, the author could compare the effects of the treatment procedure upon one class of problem behaviors to the effects of the baseline procedure upon other classes of problem behaviors within the same module.
Results

Across three consecutive modules (modules one, two, and three), the author observed increases in the plotted frequencies of subject correct answers, decreases in the plotted frequencies of subject incorrect answers, and/or increases in plotted percentages of subject correct answers (accuracies) coincident with introduction of algorithmic problem-solving treatment procedures. (See figures 9, 12, and 13.)

Discussion of Results

The following methodological issues must be addressed in order to assess validity of the author's findings: (a) the number of data points necessary to demonstrate a valid treatment effect, (b) the importance of concurrently observing both treated and untreated problem behaviors, (c) the extent to which different forms of each module quiz were equivalent, (d) the extent to which different forms of each module quiz contained novel items, (e) the extent to which quiz items were equivalent to intervention items, (f) possible interactions between baseline and treatment procedures, and (g) possible interactions between testing and treatment procedures.
Figure 12. Module two percentage correct/incorrect and frequency correct/incorrect by Julian day.
Figure 13. Module three percentage correct/incorrect and frequency correct/incorrect by Julian day.
1. An insufficient number of data points were collected to demonstrate a valid treatment effect. According to Cook and Campbell (1979), a minimum of 50 observations are necessary to sort treatment variability statistically from other sources of variability. Behaviorologists have traditionally relied upon visual inspection of their graphed data, rather than statistical analysis, to demonstrate a valid treatment effect (Johnston & Pennypacker, 1975). Although fewer than 50 points are usually required to demonstrate a valid effect by visual inspection, a sufficient number of points must be provided both before and after an intervention to convince the reader that data changes were a function of the experimenter's intervention rather than other sources of variability. The author did not collect a sufficient number of data points to validly demonstrate a treatment effect, by either visual inspection or statistical standards.

2. The importance of concurrently observing both treated and untreated problem behaviors. Concurrent observations of both treated and untreated problem behaviors can provide additional evidence that changes in the problem behaviors receiving treatment are a function of that treatment and not due to other sources of
variability in subject behavior. A change in the behavior receiving
- treatment, while concurrently observed but untreated behaviors
- remain stable, provides additional validity for experimenter claims
- that behavioral change is a function of treatment procedures
- (Johnston & Pennypacker, 1975; Miller, 1980).

No concurrent observations were made of the treated and
untreated problem behaviors in modules one and two. However,
treated and untreated behaviors were concurrently observed in
module three. Although desired changes in three of the four treated
behaviors coincided with application of treatment procedure,
concurrently observed but untreated behaviors did not remain stable
(see Figure 14). These data suggest that either: (a) Untreated
problem behaviors were affected by the treatment procedure applied
to the targeted behavior (perhaps the untreated behaviors were not
functionally independent of the treated behaviors), or (b) other
sources of variability, such as variations in the quiz items, were
responsible for changes in untreated problem behaviors.

3. The extent to which different forms of each module quiz were
equivalent. An experimenter must consider whether variations in
subject behavior could reasonably be attributed to variations in the
Figure 14. Multiple baseline of module three problem behaviors by objective, number correct by Julian day.
items across different forms of a quiz. If a form had "easier" items then an increase in accuracies or frequencies of correct responses might be due to a variation in the experimenter's measurement instrument rather than to a specified intervention. The multiple baseline graph of the subject's responses to module three items reveals some variability in the subject's baseline responding across quiz administrations. (See Figure 14.) However, changes in subject problem behavior coinciding with treatment interventions for module one, two, and three behaviors are visibly greater than the changes in problem behaviors observed during baseline conditions, as can be seen by examining the frequency and accuracy graphs of the problem behaviors in modules one, two, and three. (See figures 9, 12, and 13.) Of course, if the author had obtained repeated and stable measures of the problem behaviors following each intervention, such data would have added validity to the author's conclusions that changes in performance were due to the intervention, rather than to variations in the measurement instrument.

4. The extent to which different forms of each module quiz contained novel items. An inspection of module one quiz items
revealed that different forms of the quizzes had a number of identical items. As the author's algorithmic problem-solving training procedure included presenting items from previously administered forms of module quizzes, module one data do not demonstrate that the algorithmic problem-solving procedure effectively produced increases in subject problem behavior with respect to novel problem items.

However, the module two and three quiz forms administered immediately before and after the first introduction of treatment procedure did not contain any identical items. The module two quiz forms administered immediately before and after the second introduction of treatment procedure had only one identical item for which the subject's performance changed from incorrect to correct. The module three quiz forms administered immediately before and after the second introduction of treatment procedure had only two identical items for which subject's performance changed from incorrect to correct. Neither module had a sufficient number of identical items to account for the large changes in subject performance that coincided with introduction of treatment procedure. Thus data from the subject's performance on module's
two and three suggest that algorithmic problem-solving training improved subject performance on novel problem items.

5. The extent to which quiz items were equivalent to intervention items. Module four quiz items required different problem behaviors than those trained during intervention. The lack of correspondence between training and test items made module four quiz items unusable as measures of change in problem behavior.

6. Possible interactions between baseline and treatment procedures. A sequence of baseline procedures were implemented for the problem behaviors in modules one and two. (See Table 1.) These procedures included traditional tutoring techniques. Were changes in module one and two problem behavior that coincided with the introduction of treatment due to an interaction between treatment and baseline procedure? Baseline procedures were altered for module three problem behaviors. In module three, only Baseline I procedures were in effect. No tutoring was given prior to the introduction of treatment procedures. Yet, desired changes in module three problem behaviors coincided with the introduction of treatment procedures, for three out of four problem behaviors. Therefore, changes in problem behaviors in module three did not
appear to depend upon interactions between baseline and treatment procedure.

7. Possible interactions between testing and treatment procedure. Were changes in problem behavior the result of repeated quizzing prior to intervention? The number of quizzes given prior to the initial intervention for module problem behavior varied from five to two, with five quizzes given prior to intervention for module one problem behaviors, four quizzes given prior to intervention for module two behaviors, and two quizzes given prior to intervention for module three behaviors. Desired increases in problem behavior coincided with the initial introduction of treatment procedure in modules one and two, but not module three, suggesting that testing procedure may have interacted with treatment procedure.

Treatment procedure was implemented for module three behavior according to a multiple baseline design. Algorithmic problem-solving training was applied to specified module three problem behaviors, while baseline procedure remained in effect for other problem behaviors in the module. For three out of four targeted problem behaviors, increases in number correct coincided with introduction of treatment procedure, even though treatment
was implemented after different numbers of tests had been given for the different target behaviors (see Figure 14). Thus, testing procedure does not seem to have interacted with treatment procedure to produce changes in problem behavior.

To summarize, design and measurement problems with the author's empirical analysis of a technique to teach algorithmic problem-solving limit its validity. However, several aspects of the data do suggest that algorithmic problem-solving training may indeed produce increases in the frequency and accuracy of subject problem behavior. The author found that increases in the frequency of correct responding, decreases in the frequency of incorrect responding, and increases in accuracy coincided with initial treatment intervention for problem behaviors in modules one and two. The author found that reintroduction of treatment procedure three months after the initial intervention coincided with increases in accuracy and decreases in the frequency of incorrect responding on module one, two and three quiz items, as well as increases in the frequency of correct responding on module three items. Finally, when treatment procedure was introduced for module three problem behaviors according to a multiple baseline design, the author found
that treatment coincided with increases in three of the four problem behaviors targeted for intervention. Thus, some of the author's data do suggest that training algorithmic problem-solving behaviors may produce increases in correct problem behaviors on example identification tasks. Further research on techniques to teach algorithmic problem-solving is warranted.

Suggestions for Further Research

Teaching Novel Algorithmic Problem-Solving Behavior

If students could formulate their own algorithms for effective problem-solving behavior, they would become less dependent upon teacher formulated algorithms. Several techniques may be effective in establishing algorithm-formulating behaviors.

Inductive algorithm-formulating procedure. One technique for teaching algorithm-formulating behavior is to present a class of relatively easy problems, problems for which the student already has problem-solving behavior in some strength. The teacher asks the student to specify the problem-solving behaviors emitted as he or she solves each problem (Vaughan, M.E., 1985). The teacher applies prompting, reinforcement, and correction procedures to establish accurate self-descriptive behavior. The student is
learning to formulate an algorithm for solving the class of problems. The student is required to test the newly formulated algorithm by applying it to a series of similar problems and to revise the algorithm until it becomes effective. It may be useful to have the student teach another student to state and follow the algorithm effectively. If the algorithm is ineffective with the novice student, the algorithm-formulater would then be required to revise it. Once a student can formulate effective algorithms for easy problems, the teacher may begin to introduce more and more difficult problems. A similar procedure was described in a theoretical article by Palumbo and Vargas (in press) and was applied to teach three junior high students to work quadratic equations (Palumbo & Palumbo, manuscript in preparation).

The author's study of algorithmic problem-solving provides some interesting anecdotal data on algorithm-formulating behavior. As algorithmic training was repeatedly given for different problems, the subject began to suggest revisions in the algorithms formulated by the author, when the algorithms were ineffective for the subject's problem behavior. Another procedure to teach algorithm formulating behavior might be to: (a) provide a reinforcement
history for algorithmic problem-solving with teacher-formulated algorithms, (b) gradually provide more and more incomplete algorithms for similar classes of problem behavior, (c) prompt and reinforce student revisions of the incomplete algorithms into complete algorithms that effectively change the problem behavior until, (d) the student is formulating novel but effective algorithms without teacher assistance.

Deductive algorithm-formulating procedure. It may be useful for teachers to compose algorithms for algorithm-formulating behavior and to teach students to state and follow those algorithm-formulating algorithms correctly. For example, students could be taught to state and follow an algorithm for formulating concept identification algorithms from the definitions of concepts in any subject matter. (See Figure 15.)

Teaching First- and Second-Order Problem-Solving Behavior


First-order problem-solving behavior.

When a student has learned to recognize various kinds of problems and apply relevant techniques, he does not seem to be
1. List the concept's properties as stated in the definition.

2. Ask whether each of the defined properties is present or absent in the example.

3. If the example has all the properties listed, the item is a positive example of the concept. If the example lacks one or more of the properties listed, the item is a negative example of the concept.

Figure 15. Algorithm for formulating concept identification algorithms from concept definitions.
thinking at all. His behavior is perhaps one step removed from reinforcement, but it is still nothing more than a set of responses of specified topography evoked by specified occasions. (p. 21)

The previously described problem-solving behaviors are an example of first-order problem-solving. Stating and following algorithmic instructions are behaviors one step removed from the reinforcement of a problem behavior.

**Second-order problem-solving behavior.** Skinner describes second-order problem-solving behavior as follows: "... the behavior which solves the problem of solving problems is one further remove from ultimate reinforcement" (p. 22). Skinner cites Polya's book *How To Solve It* (1945) as "concerned with teaching students how to solve not first-order problems, but the second-order problem of discovering first-order techniques" (p. 22). Types of second-order problem-solving behavior include: (a) classifying a problem, (b) doing a structural analysis of a problem, (c) doing a functional analysis of a problem, (d) restating a problem in a different form, (e) dividing a problem into subproblems, and (f) formulating an algorithm for solving a problem.
1. A problem-solver may classify a problem as a type for which the individual already has effective problem-solving behaviors. Polya (1962) provides an example of problem-classifying behavior:

A student is taking a written exam in math. . . . After having read a proposed problem, he may ask himself "what kind of problem is this?" . . . If he can classify his problem, recognize its type, place it in such a chapter of his textbook, he has made some progress. He may now recall the method he has learned for solving this type of problem. (p. 118)

Polya describes two general types of problems: problems to find and problems to prove.

The aim of a "problem to find" is to find (construct, produce, obtain, identify, . . . a certain object, the unknown of the problem. The aim of a "problem to prove" is to decide whether a certain assertion is true or false, to prove or disprove it. For instance, when you ask "What did he say?" you pose a problem to find. Yet, when you ask "Did he say that?" you pose a problem to prove. (p. 119)

As Polya states "it may be useful to classify problems, to distinguish problems of various types. A good classification should
introduce such types that the type of problem may suggest the type of solution" (p. 118). For example, classifying a problem as a problem to find or a problem to prove may allow the problem-solver to emit the next type of problem-solving behavior.

2. The problem-solver may do a structural analysis of a problem, by specifying its defining components. For example, if a problem has been identified as a problem to find, the problem-solver may proceed by identifying the different parts of the problem: its unknown, its conditions, and its data (Polya, 1962). Polya defines the unknown of a problem as follows:

The unknown may be of every imaginable category. In a problem of geometric construction the unknown is a figure, for instance a triangle. When we are solving an algebraic equation, our unknown is a number, a root of that equation. When we ask “What did he say?” the unknown may be a word, or a sequence of words, a sentence, or a sequence of sentences, a speech. A problem clearly stated must specify the category (the set) to which the unknown belongs; we have to know from the start what kind of unknown we are supposed to find: a triangle, or a number, or a word... (p. 119)
Thus the unknown is the problem behavior to be strengthened by the individual’s various problem-solving behaviors.

Polya describes the relationship between the problem’s unknown, its condition and its solution as follows:

In the set of objects specified by the problem to which the unknown must belong, there is a subset of those objects that satisfy the condition, and any object belonging to his subset is called a solution. (pp. 119-120)

Thus the condition is a constraint that determines which members of the category to which the unknown problem behavior belongs will be reinforced. A condition is a rule for the correct identification of the problem behavior.

Polya coined the term *data* to:

... denote all the given (known, granted...) objects (or their full set) connected with the unknown by the condition. If the problem is to construct a triangle from its sides a, b, c, the data are the three line segments a, b, and c. (p. 120)

The data, the conditions, and the unknown are potential discriminative stimuli for the individual’s first-order problem-solving behaviors. By specifying the data, the conditions,
and the category of the unknown, the problem-solver can strengthen problem-solving behaviors that will produce desired changes in a problem behavior. Consider the following problem: "Given six toothpicks (the data), construct a figure (the unknown) that meets the following condition: the figure must contain four triangles."

Certain assumptions are sometimes made by the problem-solver and those assumptions can strengthen behavior incompatible with desired changes in the problem behavior. If the problem-solver assumes that the toothpicks must be arranged in two dimensions (not a condition of the problem), then the desired problem behavior, arranging the toothpicks in three dimensions so that they form a pyramid, will not occur (personal conversation with Slocum, 1987). Thus, by specifying the components of a problem: the unknown, the conditions, and the data, the problem itself can be changed in ways that strengthen other problem-solving behaviors.

3. The problem-solver may do a functional analysis of a problem, that is, specify the controls over a problem behavior. For example, the problem-solver may identify the reasons why he or she eats excessively between meals or the reasons why he or she labels an example of an extinction process as a punishment process.
4. The problem-solver may restate a problem, as in rewriting a word problem in algebraic terms. As Skinner (1984) states: "reducing the statement of a problem to symbols does not solve the problem, but by eliminating possibly irrelevant responses, it may make first-order problem-solving more effective" (p. 586).

5. The problem-solver may divide a problem into simpler component problems. Changing one problem behavior may change the remaining problem situation so that the remaining problem behaviors can also be effectively altered. For example, to solve a problem of determining what form of transportation will take us from point A to point B with the least cost, we might divide the problem into several smaller problems. We must first determine the dates and times of travel before we can determine the cheapest mode of transportation. As the reader knows, costs per mile for different forms of transportation vary depending upon the time of day, the day of the week, the season, and the number of days between ticket purchase and date of travel. Once dates of departure and return have been determined, the remaining parts of the problem can be solved.

6. Lastly, the problem-solver may formulate new algorithms for specified classes of problem behavior, as the author has previously
discussed.

In summary, second-order problem-solving behavior is any behavior that changes a problem situation so that previously acquired first-order problem-solving behaviors will occur and effectively change a problem behavior.

Heuristic-Stating Behaviors

Skinner (1984) defined and classified heuristics as a type of rule: Many rules which help in solving the problem of solving problems are familiar. "Ask yourself 'What is the unknown?"' is a useful bit of advice which leads not to a solution but to a modified statement to which a first-order rule may then be applied. . . . Second-order "heuristic" rules are often thought to specify more creative or less mechanical activities than the rules in first-order (possibly algorithmic) problem solving, but once a heuristic rule has been formulated, it can be followed as "mechanically" as any first-order rule. (p. 586)

A heuristic, from the Greek *heuriskein* "to invent or discover" (*Webster's New 20th Century Dictionary Unabridged*, 1977, p. 856) is a procedure which "... can be stated in terms that are sufficiently general to be prima facie applicable to nearly any problem domain"
(Nickerson & Perkins, 1985, p. 82). Here is an example of a heuristic originally offered by Polyá (1945), as described by Nickerson and Perkins:

If one way of representing a problem does not lead to the solution try to restate or reformulate the problem; Break the problem into parts. If the parts are not manageable break those into smaller parts. Continue until you arrive at problems of manageable size. (pp. 76-82)

Algorithms, unlike heuristics, are rules specific to a limited class of problems. For example, a set of instructions for solving a quadratic equation is an algorithmic rule. Different algorithms must be taught for different types of algebra problems. Heuristics are more general types of rules, which may be useful in solving a wide variety of problems. For example, when solving mathematical and other types of problems, a valuable heuristic might be “Restate the problem in an equivalent form.” Heuristics are rules for second-order problem-solving behaviors that facilitate other problem-solving behaviors, such as the generation or application of algorithmic rules to a wide variety of problems. The heuristic “Restate the problem in an equivalent form” may occasion the
behavior of restating an algebra word problem in a quantitative form. Once a problem has been restated in quantitative form, it may now occasion previously learned problem-solving behaviors such as performing commutative and associative operations on the problem. Reciting a heuristic such as "Restate the problem" can be useful for many types of problems. Some problems become solvable when they have been restated in Venn Diagram form, rather than quantitative form. Thus, while different algorithms must be taught for different types of algebra problems, a heuristic might be useful in solving a wide variety of problems. Heuristics are rules specifying behaviors that will change problem situations, so that other problem-solving behaviors such as algorithmic rule-stating will occur and lead to desired changes in a problem behavior.

Teaching Heuristic-Formulating Behavior

How might one teach students to formulate heuristics? One technique might be to provide students with histories of reinforcement for first- and second-order problem-solving in a wide variety of problem situations. As students became effective problem-solvers, they would also be taught to describe their problem-solving behaviors. Students who can accurately describe
their first- and second-order problem-solving behaviors may eventually begin to discover their own heuristics for problem-solving. Thus, teachers might begin to simulate the conditions which were perhaps responsible for the heuristic-formulating behaviors that have occurred in individuals like Skinner and Polya.

Teaching Second-Order Problem-Solving Behavior

Presumably, students could be taught second-order problem-solving behavior by applying the same techniques that have already been suggested for the teaching of first-order problem-solving behavior. The teacher might apply prompting, reinforcement, and correction procedures to establish heuristic-stating and heuristic-following behavior (or any other type of second-order problem-solving behavior) in the presence of a wide variety of problem situations to which the heuristic could be applied. Once a second order problem-solving relation had been established, the teacher could then begin to fade teacher assistance, so that control of the behavior-behavior/environment relation could shift to the problem situation itself.
Cultural Survival and Effective Teaching Technology

If, as H.G. Wells (1920) once said, "Human history becomes more and more a race between education and catastrophe" (p. 594), then the only hope, for both our culture and our species, is the development and implementation of effective and efficient teaching technologies.

The instructional methods derived from an Experimental Analysis of Behavior have already demonstrated their power in the transmission of subject matters and basic skills. ... They may even be more successful when applied to the intellectual self-management called thinking. (Skinner, 1966, pp. 35-6)

As behaviorologists, we have the necessary repertoires for the further development of an effective and efficient technology of teaching. If we are concerned for the survival of our culture, we must continue to develop and apply that technology to the teaching of complex repertoires such as problem-solving.
CHAPTER REFERENCES


FOOTNOTES

1The term Behaviorology has been proposed by a number of different authors (e.g., Fraley & Vargas, 1986; Horcones, 1986), as a name for "the study of behavior and its related events"; - ology, as the suffix, indicates "a discipline or domain of scientific study" and behavior-, as the stem, denotes the subject of study, "behavior and its related events" (Fraley & Vargas, 1986, pp. 56-57).

2As Hayes and Brownstein (1986) have argued: "No matter how dynamically one behavioral event may be intertwined with other behavioral events within the same individual, however, for a contextualist a behavior-behavior relation is a phenomenon to be explained by appealing to particular contextual arrangements (e.g., contingencies of reinforcement) that might permit prediction and control of the behavior-behavior relation itself" (p. 185).

3See Vargas (in press) for a motivative/discrimination classification of problem-solving.
Skinner (1969) makes a similar distinction when he says that "sometimes the problem is not what to do but whether to do it" (p. 152).

A postcedent event has been defined as any environmental change following a response. A postcedent may or may not be contingent upon (therefore a consequence of) the response (Vargas, 1984).

An establishing operation has been defined as a environmental event or operation that changes both the functional value of postcedent events and the probability of all behaviors that have produced those postcedents in the past (Michael, 1982).

Skinner (1969) defines a concept as a class of stimuli with one or more common properties.

See Skinner (1984) for a definition of maps as spatial representations of rules: "the relation between a behavior and its reinforcing consequences can be represented spatially" (p. 586).

Many behaviorologists have developed schematic representations of the basic behavioral processes. The author's schematics evolved from those originally used by Sigrid Glenn.
10 As Catania (1984) has stated: "Thus the decrease in responding during extinction is not a special process requiring a separate treatment; rather it is part of the process generated by the reinforcement operation" (p. 68).

11 One may describe a discrimination process as the discriminative control of a two-term relation, such as reinforcement or punishment, rather than as the discriminative control of a behavior (Sidman, 1986). The terms discriminated reinforcement and discriminated punishment are suggested as terms for these three-term relations, as they are subtypes of the class of three term relation called a discriminated operant (Catania, 1984).

12 To be consistent with Sidman's definition of discrimination, one may describe a generalization process as the generalized control of a two-term relation, such as reinforcement or punishment, rather than as the generalized control of a behavior. Thus the terms generalized reinforcement and generalized punishment seem appropriate.
A positive example of a concept is an example that has all the defining properties of a concept. A negative example of a concept is an example that lacks one or more of the defining properties of that concept (Englemann & Carnine, 1982).

Fraley and Vargas (1976) have defined a module as a unit of instruction that includes a set of behavioral objectives, test items designed to assess the behaviors specified in those objectives, and instructional activities designed to teach those behaviors.

According to J. S. Vargas (1977), an explanatory fiction is a "statement that has the form of an explanation but in which the cause which is given is really only another way of describing the behavior which is supposedly being explained" (p. 22). Or as Skinner (1953) has stated, an explanatory fiction exists when "a single set of facts is described by two different statements, and one statement is explained in terms of the other" (p. 31).

An explanation is a statement that specifies two different observable events. One event is said to cause the other (Bruce, 1987).
17 According to MacCorquodale and Meehl (1948), a hypothetical construct "involves the supposition of entities or processes not among the observed" (pp. 106-107).

18 The Julian day calendar is an astronomical system of numbering days consecutively from the year 4713 B.C. (Webster's Third New International Dictionary of the English Language Unabridged, 1969, p. 1224). In the educational 105 system, Julian days were numbered consecutively from the first day of the current year.

19 Miller & Weaver's (1975) term for their algorithmic problem-solving training procedure is *concept programming* (p. 45).

20 Englemann & Carnine's term for algorithm is *cognitive routine*, defined as "a series of steps that solves a problem of a given type" (p. 195).
REFERENCES


Johnston, J.M. (1975). "... to beat back the frontiers of ignorance."


