Book Review

A Review of *Theory of Instruction* by Seigfried Engelmann and Douglas Carnine

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Theory of Instruction is the most formal presentation to date of the principles underlying the DISTAR Reading, Language and Math curricula.¹ DISTAR should be of interest to behavior analysts for two reasons: 1) These materials have been shown to have significant impact upon the academic performance of "hard-to-teach" students, and 2) While DISTAR was not derived from the experimental analysis of behavior, its procedures for establishing stimulus control are more complex than those embedded in many "behaviorally-based" curricula.

Historical Background— The Follow Through Project

DISTAR was developed during Follow Through, a federally funded research project intended to expand upon the goals of Head Start. Funding was authorized in 1967 for the purpose of discovering educational practices effective with disadvantaged elementary school pupils. The objective was to obtain achievement levels similar to those of more advantaged students. Nationally known educational researchers, including Seigfried Engelmann and Wesley Becker, were invited to submit proposals. Their model, known as the Engelmann-Becker Direct

Instruction model, was one of those selected for funding. Other models represented widely varying educational philosophies including Piaget's theory of cognitive development and "Open Classroom" and "language experience" approaches. All models were supported at the same level with monies providing for materials, staff training, etc. By 1978 almost 750,000 elementary public school students in 170 communities had participated in Follow Through at a cost of \$59 million (Becker, 1978).

An extensive and controversial evaluation of the Follow Through models was conducted by Abt Associates of Cambridge, Mass. (1976, 1977).² The results indicated that the Engelmann-Becker Direct Instruction model was very effective in achieving project goals. Data from the other models were unimpressive for the most part. In many cases the performance of these pupils was virtually indistinguishable from, or worse than, that of the control groups.

Students in the Engelmann-Becker Direct Instruction model were taught in small groups in which they were required to make overt responses at a high rate. This responding was often choral, meaning that the students answered the teachers' questions in unison. Engelmann-Becker teachers utilized teaching scripts (i.e., DISTAR) that specified the examples to be utilized during teaching as well as other aspects of teacher behavior (e.g., immediate correction of errors). In short, the methods and materials utilized in this

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¹ These same principles have been incorporated into other instructional programs authored by Engelmann and his colleagues, e.g., Corrective Reading, Corrective Math. For a complete listing of available programs contact the Association for Direct Instruction, P.O. Box 10252, Eugene, Oregon, 97440.

² See Becker (1978) for specific criticisms of the Abt evaluation.

Follow Through model incorporated all the basic principles of a behavioral approach to teaching: mastery was required before more complex tasks were presented, difficult discriminations were prompted, correct answers were reinforced, etc.

It is not especially difficult to explain the poor performance of the other models; one need only appeal to their non-behavioral features. Similarly, the effectiveness of the Englemann-Becker model can be analyzed in terms of the teaching technology inherent in Direct Instruction. However, this analysis proves superficial when other Follow Through data are reviewed.

One of the models participating in Follow Through was, in fact, termed the "Behavior Analysis" model. Sponsored by Don Bushell of the University of Kansas, this model also called for the systematic application of behavioral principles. The Behavior Analysis model generally fared better on the dependent measures than many of the others, but proved substantially less effective than Direct Instruction. Where the subjects participating in the Direct Instruction model essentially achieved project goals (50th percentile on measures of reading, language, and math achievement), the same can not be said for those in the Behavior Analysis model. Students participating in this model performed at the 34th, 28th, and 22nd percentiles on measures of reading, math, and language, respectively. Spelling scores were more encouraging, with performance averaging at the 49th percentile (Becker, 1978). These data demand further study. What variables were responsible for the disparate results? While there may be other functional differences, one critical variable may have been the curricula. Where the Behavior Analysis model made use of instructional materials already available in the public schools, the Englemann-Becker model developed its own (i.e., DISTAR). The principles and procedures underlying the design of these curricula comprise the content of *Theory of Instruction*.

Rule-Governed Curriculum Design

The basic analysis presented by the authors is that academic repertoires can be classified as different types of stimulus-response relations. The classification system ignores content area (e.g., reading) while focusing on characteristics of the antecedent stimuli and the responses that they control. (In this way it is not dissimilar to Skinner's approach to verbal behavior.) The authors further pose a set of rules to teach efficiently each academic repertoire, with efficiency defined as maximum generalization following training with a minimum number of examples. While the rules vary for different stimulus-response relations, all are based upon five design features, termed "juxtaposition principles." The following example from the text demonstrates the analysis and how it can be applied to teach a particular skill (p. 50). Suppose you wanted to design curriculum to teach discrimination of words ending in voiced versus unvoiced sounds. A reasonable approach would involve providing a rule about voiced sounds, modeling a range of examples, presenting a large number of words that the students are required to respond to, and differentially consequence those responses. Given sufficient practice, most students would master this discrimination.

However, Engelmann and Carnine suggest that this general approach is an inefficient method even for those who would acquire the skill. While they might also construct a rule, model examples, and differentially consequence student responses, the script in Table 1 shows just how carefully the examples and their sequence would be prescribed.

While Engelmann and Carnine would agree to the importance of testing for concept acquisition with different examples (and teaching with those examples if necessary), they assert that this sequence would be one of the most efficient for initial instruction. This confidence is based upon the ways in which stimulus control is developed through the five juxtaposition principles.

TABLE 1

Example	Example type	Teacher wording
1. Mack	Negative	"I'll say some words. Then I'll tell you if each word ends in a voiced sound. Mack. It doesn't end in a voiced sound."
2. Mass	Negative	"Mass. It doesn't end in a voiced sound."
3. Maz	Positive	"Maz. It ends in a voiced sound."
4. Mag	Positive	"Mag. It ends in a voiced sound."
5. Mad	Positive	"Mad. It ends in a voiced sound."
6. Mat	Negative	"Mat. Does it end in a voiced sound?" (student responds)
7. Mass	Negative	"Mass. Does it end in a voiced sound?" (student responds)
8. Mab	Positive	"Mab. Does it end in a voiced sound?" (student responds)
9. Maff	Negative	"Maff. Does it end in a voiced sound?" (student responds)
10. Mal	Positive	"Mal. Does it end in a voiced sound?" (student responds)
11. Mat	Negative	"Mat. Does it end in a voiced sound?" (student responds)
12. Mav	Positive	"Mav. Does it end in a voiced sound?" (student responds)

(To the Reader: If after completing the sequence you still can't make the discrimination, repeat the examples with your fingers touching your vocal cords.)

1) First, the *wording principle* (bracket "A") is followed. This principle requires that the teacher's verbal behavior be as similar as possible for all examples. The practice permits the student to attend to details of the *example* rather than irrelevant, and potentially troublesome, variations in teacher verbage.

2) Bracket "B" indicates ways in which the *setup principle* is utilized. The *setup principle* requires that all examples (i.e., S+ and S-) share as many stimulus characteristics as possible. Thus, examples of voiced and unvoiced endings are all three-phoneme words, and share the same first two sounds (m/a/). Consider the faulty stimulus control that might develop if the following words had replaced the first three examples: cat, kiss, and surprise. Behavior might come to be controlled by the length of the word or the beginning sound, rather than the critical feature.

The authors recognize that adherence to the *wording and set up principles* may lead to rather narrow discriminative performance. That is, students presented with different examples and/or different instructions, may fail to respond correctly. However, Engelmann and Car-nine contend that it would still be more efficient to utilize these two principles and

deal with generalization in a systematic fashion at a later date through carefully selected variations in wording and setup.

3) The two "C" brackets show application of the *difference principle* to the sequence. This principle calls for the successive presentation of positive and negative examples which differ *minimally* from one another. Sequences which incorporate this design feature will minimize the degree of inappropriate generalization. The "sss" and "zzz" sounds involve almost identical topographies, but vary along the critical element: voicing. Positioning these two highly similar examples together facilitates discrimination of the critical feature, much more so than if they had been separated by other examples.

4) The *sameness principle* is indicated by bracket "D." This principle requires that positive examples be reasonably different from one another. This design practice helps ensure appropriate generalization and minimize the number of examples needed during instruction. The sameness principle also requires that these same positive examples be juxtaposed rather than separated by negative examples. The assertion being that such juxtapositioning generates superior generalization.

5) The fifth principle (bracket "E"), the *testing principle*, simply calls for the presentation of test items, the correct answers to which form no predictable pattern. When this principle is followed,

the teacher can determine if student behavior is under the control of test item sequence and can respond appropriately.

Few behavior analysts would argue with these design practices; their value in developing stimulus control has been, or could be, derived from the experimental analysis of behavior. But nowhere in the applied behavior analysis literature have they been described so neatly. Furthermore, this short instructional sequence is based not only upon the five juxtaposition principles but also the rules for teaching this particular type of academic repertoire. These rules specify not only how many positive and negative examples to present, but also their order, characteristics, and number to be modeled by the teacher. And because the analysis is content-free, the same rules that were utilized to design this curriculum are also applicable to other single-dimension concepts such as "over" vs. "not over," equivalence of numbers, etc. The authors also provide specific rules for designing curricula for other academic repertoires (e.g., "cognitive routines," a.k.a. rule-governed problem solving). Thus, once a task has been identified as part of a particular academic repertoire, rules are provided for teaching it.

Relationship to Behavior Analysis

Research into educational practices has long been an important activity of behavior analysts, with considerable effort directed towards a description of functional relations in the classroom. It appears, however, that much of the applied research has not been concerned with a *detailed, a priori* analysis of the antecedent stimuli that evoke generalized academic repertoires.

One example of this approach has been the development and testing of instructional packages that teach a particular academic or social behavior. Values of the independent variable in these cases often consist of differential consequences, modeling, behavioral rehearsal, or level of prompting, but rarely an in depth treatment of the characteristics or sequences of relevant antecedent stimuli.

In contrast, basic researchers have been very attentive to the critical nature of such variables. Terrace (1963) was one of the first to study differential effects caused by variations in the stimulus complex. Since then our knowledge in this area has become more intricate. We now appreciate the distinction between stimulus shaping and fading (Schilmoeller, Schilmoeller, Etzel, & LeBlanc, 1979). Similarly, stimulus equivalence training as delineated by Sidman, Cresson, & Willson-Morris, (1974) offers the promise of more efficient instructional methodologies. But the immediate value of these functional relations is still fairly limited for the practitioner. For example, it may not be clear how to make use of these findings if the task is to teach when multiplication, rather than addition, algorithms are appropriate for word problems. Without rules to govern the integration of findings from basic research, the curriculum evolving from behavior analysis has been neither plentiful nor especially sophisticated. Once the basic maxims of teaching (e.g., presenting a range of examples, modeling the desired performance, etc.) have been invoked, the behavior analyst still must "make it up" as he or she goes along. Consequently, the tendency is to either design materials that are (probably) less than maximally efficient or utilize the defective curriculum already in existence. In fact, only a few of the behavioral teaching technologies involve any sort of extensive curricular analysis or development.

However, *Theory of Instruction* makes it possible for curriculum design to become rule-governed. Rules, which integrate various procedures for developing stimulus control, make these procedures usable by applied behavior analysts. Thus, the instructional material can reflect all the advantages of rule-governed (versus trial and error) behavior. Most importantly, these rules have empirical support. In addition to research conducted by Engelmann and his colleagues, they are corroborated by findings from the stimulus control lab.

For example, the early work of Jenkins & Harrison (1960, 1962) can be inter-

puted as indirect support for the difference principle. Their results showed that the steepness of the generalization gradient was functionally related to discrimination training with S- and the similarity of S- to S+. Similarly, DISTAR Reading, first published in 1969, makes extensive use of stimulus shaping, as opposed to fading, procedures to teach difficult sound/symbol discriminations. The sound "th" (as in "this") is initially presented as "th." This modification is intended of course to minimize errors that might be induced by training with "t" and "h," which constitute separate phonemic elements. Rather than modify this stimulus along an irrelevant dimension such as size or color, Engelmann elected to change the critical dimension: proximity of the letters to each other. One aspect of the control exerted by juxtapositioning has also been investigated by basic operant researchers. The peak shift often found in measures of generalization has been related to the temporal sequencing of S+ and S- during training (e.g., Rosen and Terrace, 1975). However, it would be a mistake to assume that all of Engelmann's procedures have been "done before" by operant psychologists. Those interested in procedures for developing stimulus control will be intrigued by some of Engelmann's techniques. While they all seem hauntingly familiar, the behavior analyst will be hard-pressed to find exact analogues for some in the operant literature.

An obvious comparison to *Theory of Instruction* is Tiemann and Markel's (1983) second edition of *Analyzing Instructional Content: A Guide to Instruction and Evaluation*. Like, Engelmann and Carnine's text, *Analyzing Instructional Content* provides a classification system for academic repertoires as well as *guidelines* for teaching each type. While the Tiemann and Markel text is replete with examples and procedures for identifying the range of teaching examples (two weak points of the Engelmann and Carnine text), it is vague as to how these examples should be presented. In general, its procedures lack the sophistication found in *Theory of Instruction*.

Despite its usefulness, this book is not without weaknesses. While it was rewritten 12 times prior to publication (indicating both the complexity of the subject matter and the authors' desire to make it useful), there are still problem areas. Complaints from those who have used it as a text for training teachers center upon the limited number of examples used to demonstrate particular design strategies. Furthermore, some of the terminology is not consistent throughout the text. It is also true that the analysis is less clear in some places than others, and a few of the suggested practices seem arbitrary or without sufficient empirical evidence. However, the final chapters contain summaries of research findings which support the majority of the design strategies. This feature alone sets it apart from most curriculum design guides.

One final warning: this book is not for the "faint-hearted." Its language is technical and specific to direct instruction; the reader must be prepared to acquire a new verbal repertoire. In addition, *Theory of Instruction* will not be read by those behaviorists who cannot get past cognitive statements which refer to the student as "a receiver . . . of communications." But it is not especially difficult to do the behavioral translations, and it is important they be done. Engelmann and his colleagues seem to have mastered an aspect of teaching that behavior analysis has not yet thoroughly addressed. It is also likely that the experimental analysis of behavior has something to contribute to the procedures presented in this book. Engelmann is concerned with a very practical problem: establishing procedures and curricula that can be utilized effectively by teachers. The nature of this task, as well as some of Engelmann's own biases, obviate him from any detailed examination of the variables critical to the effectiveness of some of these procedures. However, operant researchers are well-prepared for such an undertaking.

In summary, it will require considerable behavior to make use of the material presented in *Theory of Instruction*. But the compatibility of the design principles with research findings from the experi-

mental analysis of behavior and the compelling nature of the Follow Through data make it well worth the effort.

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