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ABSTRACT

This paper illustrates the use of a behavioral analysis of completed curriculum materials as an extremely useful technique for identifying a gradual progression in task difficulty appropriate to the to-be-learned higher ordered behavior. Several learning resources from Pittsburgh's Learning Research and Development Center's Individualized Science Curriculum were selected for analysis for their relevance to achievement of the curriclulm's inquiry goal. The method of analysis is described as that of identifying the minimum behaviors asked of students in preceding lessons to determine if those behaviors prepare them to successfully achieve specific inquiry objectives. The curriculum materials used are briefly described. A typical Mini-Exploration was used for the analysis and is presented in the paper. References are cited. (EB)

"The Use of Gradual Progression in Establishing Higher Order Behaviors"

by

Carol Solomon

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"The Use of Gradual Progression in Establishing Higher Order Behaviors"

Carol Solomon

Scientific inquiry, productive thinking and other higher order behaviors are frequently the objectives of the new individualized elementary school curriculum materials. Yet basic research in operant laboratories has usually focused on much simpler behaviors. For the analysis of behavior, then, the existence of curriculum materials designed to teach higher order behaviors presents both a promise and a problem.

First, the problem—the materials were developed largely without guidance from the analysis of behavior, so instructional designers and educational psychologists now assume that such an analysis is useful only in teaching simpler behaviors such as discriminating the lower case letters b and d or memorizing a long-division algorithm. Yet learning principles derived from the analysis are applicable to teaching higher order behaviors and, in fact, a behavioral analysis of completed materials is an extremely useful technique for identifying a gradual progression in task difficulty appropriate to the to-be-learned higher order behavior. This paper illustrates the use of this technique, through a behavioral analysis of several learning resources from Pittsburgh's Learning Research and Development Center's Individualized Science curriculum. The learning resources were selected for their relevancy to achievement of the curriculum's inquiry goal. But first, I would like to mention briefly the promise that the existence of such materials holds for the analysis of behavior.

These curriculum materials are nothing less than promising sources for analyzing our most complex knowledge, since each must represent a task analysis of the higher order behavior it aims to teach. An elementary school science curriculum with the objective of teaching inquiry obviously must begin instruction with simpler tasks within the current ability of the novice child--tasks that may not yet look much like inquiry. Of course, a child's success in a well-designed curriculum will be contingent on performance of those tasks. Yet, these early tasks must also be true approximations to the "mature" inquiry behaviors, or else even the most carefully designed contingencies will not reliably result in establishing mature inquiry. A science curriculum with a progression in task complexity that succeeds in establishing mature inquiry represents an effective analysis of that higher order behavior.

My concern now, however, is to exemplify the use of behavior analysis to identify appropriate and inappropriate gradual progressions in tasks teaching the higher-order behavior of inquiry.

We selected LRDC's Individualized Science curriculum for this analysis precisely because we were impressed with its breakdown of the broad inquiry goal into insightful, nontrivial, yet teachable behavioral objectives. The three objectives whose teaching I will analyze here are: (1) thinking of a solution to a problem; (2) observing and applying knowledge to explain a phenomenon; and (3) proposing an alternative use of materials to solve a problem. The method of analysis is identifying the minimum behaviors asked of students in preceding lessons to determine if those behaviors prepare students to successfully achieve these three inquiry objectives. If simpler versions of the inquiry behaviors are embodied in earlier lessons, the progression in task complexity should reliably result in student success in achieving the objectives, as illustrated by the first example that will be analyzed. On the other hand, if behaviors called for in earlier lessons are not simpler versions of behaviors required by the inquiry objective, a child's success in achieving that objective would be less likely. The second and third examples I will discuss will clarify this problem. However, before plunging into the analysis, I will briefly describe the curriculum materials.

In Individualized Science, units named for individual scientists, are the basic content grouping. In each unit the two main learning resources are the lesson, usually text with guided activities and questions, and the MiniExploration (MinEx); an investigatory activity or laboratory exercise. This analysis concentrates on the MinEx's as they are designed to contribute most to achievement of the inquiry goal.

A typical MinEx nonconsumable booklet looks like this. The

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cover page presents a question and a list of the materials needed to find the answer. The child can either devise his or her own plan to find the answer or, by turning the page, can follow a detailed

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description of one child's plan that successfully answers the question. The MinEx booklet also poses questions about the investigation and the child is to record the answers and any data in a science notebook. As students become more skilled in inquiry they are to formulate their own plan for answering this question before turning the cover page to read the description of how one stt ent did it.

I might note, in passing, the contingency problem represented by the fact that students can, throughout the curriculum, select to "solve" the posed question simply by following directions. My concern here, however, is with the appropriateness of the preceding instructional tasks, rather than with whether or not they are response-contingent.

Let's look again at the cover page of Lagrange MinEx 7 to analyze

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how tasks the child has done in earlier lessons have prepared him or her to think of a solution to the question, "Does your finger exert a force on water?" Extensive experience with an equal arm balance has been provided in earlier units and the language of the question, "exerting a force," is also familiar. Also, in earlier lessons of the Lagrange unit, the child has found the relative weight of objects by comparing the amount of water they displace. Thus, it appears that all the necessary elements for answering the question posed in the MinEx have been taught; it remains for the child to put them together in what is for him or her a new way.

This situation is analogous to one described by Skinner (1968) in which Max Wertheimer attempted to teach students to discover the area of a parallelogram:

> For Wertheimer productive thinking occurs when the student 'sees' that the protuberance on one side of a parallelogram just fills the gap on the other. He must not see it because it has been pointed out to him, however. The solution must come as an insight--an idea or response which is by definition not traceable to antecedent conditions. [Yet] In Wertheimer's example, the student does not by any means start from scratch. He has an extensive repertoire acquired under similar circumstances. He understands the problem; he can calculate the area of a rectangle, and he knows something about triangles and how they differ in size and shape. He will be more likely to have this particular insight if he has solved comparable problems by cutting and arranging pieces of paper or by drawing lines to divide areas into parts. (Skinner, 1968, p. 127)

Our elementary science student, in addition to having acquired an appropriate repertoire for solving Lagrange MinEx 7, has a good prompt. The picture shows a useful arrangement of the balance and beakers of water, but does not identify exactly how these items can be used to answer the question. As Skinner (1968) has pointed out, "The best way to help the student give birth to the answer . . . is to give him a strong hint or even the whole answer, but that is not the best way to make sure that he will recall it in the future"

(p. 144). In the case of this MinEx, a "strong" hint would have been an illustration of exactly how to use the beakers to answer the ques-

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tion. That strong hint is on page 2 of the MinEx. But the behavior of following this pictorial direction is very far from the behavior of trying to solve this by sticking one's finger in the beaker. The "weak" hint given on the cover page sets up a situation in which a child who has done the earlier lessons is highly likely to be able to think of how to use the beakers to answer the question. Once the student has successfully used this weak hint to think of an answer, even weaker hints may suffice later on to elicit similar behavior.

To summarize, previous lessons have provided the student with the behaviors necessary to solve this MinEx, and the cover picture gives a suitably "weak" hint about the appropriate arrangement of materials. It seems likely then that a student who selects Lagrange MinEx 7 may well be prepared to invent the solution to the posed question, without looking at the directions provided.

On the other hand, the teaching material that prepares the child for Lavoisier MinEx 11, in which he or she must observe a phenomenon and apply knowledge to explain it, does not teach one of the behaviors <u>important</u> to student success. Lavoisier MinEx 11 poses

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the question, "How does a trick candle light itself?" This MinEx is unusual in that even beyond the cover page the child is given very brief directions: Light the trick candle, blow it out, observe it carefully, blow it out again, and observe it until it burns itself out. The child then answers questions including:

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How does the trick candle look different from other candles you have used?

How does the trick candle burn differently from other candles?

And, most important for this inquiry objective:

Explain how the trick candle lights itself.

Since you have not done the preceding lessons, I will assume that you are not ready to come up with an explanation of the trick candle! The "trick" consists of a metal core wick, noticeably heavier than normal candle wicks, that continues to glow after the flame has been blown out. The glowing wick then ignites gaseous wax that remains near the top of the candle. Consider, then, what prior experiences and knowledge a child needs to explain this phenomenon. The child must have observed wicks of normal candles, so that the relative thickness of the trick candle wick and the fact that it continues to glow after it is blown out will appear noticeably "different." The child must also know that gaseous wax located near the tip of the wick is the burning substance in a candle, and must then apply this knowledge to explain a slightly different candle-burning situation.

Looking at the activities in two earlier lessons of this unit, we see that what the child does there represents simpler versions of only some of the behaviors that will solve this MinEx. In these two earlier lessons the student observes, lights, and blows out a normal candle and answers questions like these that prompt careful observation of the wick:

Look at the wick. What is the wick made of?

What does the wick look like before it burns?

What does the tip of the wick look like when it is burning?

The observing behavior evoked by these questions will be directly useful in solving the trick candle MinEx. The observing behavior is heavily prompted by questions in this earlier lesson, and these prompts are faded out in the MinEx. Also prior to this MinEx the student learns that gaseous wax burns, while liquid and solid wax do not burn. The learning experiences include attempting and failing to light liquid and solid wax. Then, using a piece of metal screen, the student is directed to look through a candle flame to observe the clear part of the flame. This clear part is then identified for the student as burning gaseous wax. Note, however, that the trick candle MinEx requires that the child apply the knowledge that gaseous wax burns in developing an explanation for the candle's re-lighting, while the behaviors evoked in the lesson involve simply observing the clear part of the flame. In fact, the response called for, looking at the clear part of the flame, can be performed by a student who, if asked, could not identify that part as burning gaseous wax. Success at developing an explanation for the relighting phenomenon would be more likely if, in an earlier, prompted instructional situation, the student had actually applied the knowledge that gaseous wax burns. Thus, we can conclude that although the early lessons prepare the student to make careful observations of the relevant part of the trick-candle, they do not adequately prepare him or her to develop the correct explanation for that observation.

My final example, in which the earlier instructional materials do not represent simpler versions of the objective, involves finding an alternative way (other than that given in the MinEx directions) to use the materials in solving the posed problem. The value of this kind of objective in relation to an inquiry goal can hardly be overestimated. A child who, after completing a MinEx according to directions, can then propose an alternative solution, has indicated some understanding of the principles operating in both solution methods. Many MinEx's explicitly ask the child to think of an alternative solution in an optional section on the last page called "other things to try." However, simply asking for the behavior does not insure that the child will be able to give it, as the following example illustrates.

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Vesalium MinEx 1 asks, "Can you think of a way to make a system for measuring temperature?" The content of the Vesalius Unit illustrates examples of the concepts of system and subsystem; thermometers are not mentioned. Although students have used thermometers in the conventional manner in earlier units, the principles of their operation have not been taught. It seems very likely, then, that most students would have to follow carefully these MinEx directions in order to make

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an air thermometer. After having followed these directions, the MinEx suggests that the student try to rearrange the same materials to make a water thermometer.

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However, the behavior of following directions to make an air thermometer is not a less complex version of the behavior required to successfully use given materials in a new way. Following directions to make an air thermometer requires careful attention to the particulars of the given situation--how to stick the plastic tube in the stopper, how much water to put in the beaker, how to put the rubber band on the tube to mark the water level, etc. In contrast, being able to reuse the materials in a new way that implements the same principles implies that the student has first abstracted the general principles operating in a particular instance.

Gagné has described the behavior of rearranging the particulars of a situation according to certain operating principles as "a capability of applying a rule to any number of specific instances" (Gagné, 1971, p. 317). He suggests that the person who can do this successfully is one who views the stimulus situation in terms of the concepts, rather than the particulars, of which it is composed. A generally accepted method of teaching concepts involves the presentation of a series of examples, to each of which the student responds so as to assure that the basic similarities, rather than the accidental particulars, have been observed (Mechner, 1965; Markle and Tiemann, 1971). Once the principles operating in a particular instance have been observed, the student will be better prepared to reuse the materials in a new way which, nevertheless, implements these principles.

Of course, even without direct instruction designed to evoke observation of principles in a given instance, some children will, in fact, observe the principles and be able to use them successfully in designing a new solution. However, lacking such instruction, many children will fail in their first attempt to construct a new solution, and that failure may have unplanned consequences. Not only has the desired behavior not occurred and so, not been learned, but also the child may have learned the undesirable behavior of avoiding future failure by no longer attempting the "other things to try."

To sum up briefly, these examples illustrate a technique of behavioral analyses of curriculum materials that can be used to identify how well students are prepared to perform desired higher order behaviors. Such an analysis would obviously be useful in the formative evaluation stage of curriculum development, but the learning principles from which this technique is derived can offer much more. When we can arrange a series of learning tasks that reliably result in achievement of a higher order objective, we have, in effect, the most useful analysis of that complex behavior.

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