Training Designers to Think About Thinking

Susan M. Markle
Office of Instructional Resources
University of Illinois
Chicago, IL 60680

Abstract. Instructional products can be characterized as reaching three different levels of achievement: (1) students remember the information presented; (2) students can apply conceptual classification schemes, can apply rules, or can follow procedures; (3) students can discover how conceptual and rule-governed structures work. While memory is often a useful outcome, it does not imply the ability to use the knowledge. Ability to think at an adult level is an increasingly called-for outcome, especially among science educators, an outcome that calls for new ways of designing instruction. Designs that enable students to apply conceptual schemes and rules do not foster thinking skill development. The pursuit of efficiency and content coverage in instructional products will have to be sacrificed in some cases in order to train students in thinking skills.

In the beginning was the Word. The Word was given and the Word was received. In the mid-fifties, the most popular design for instruction required the programmer to construct a sequence of not more than 30 words in such a way that at least one of them occurred twice. The second coming of the important Word required student activity, namely filling in a blank. If the designer had artistic talent, the student could be assisted in this challenging task by all sorts of attention-getting devices, e.g., italics and underlining. If this did not suffice to ensure correct blank-filling behaviors, one could also manipulate the characteristics of the blank itself by providing initial letters or the correct number of spaces or by some other similar prompt. The subsequent instructional design problem was to provide enough practice—an empirically based concept—so that, given the beginning of the sentence on the post-test, most students could fill in the blank without all that prompting.

It was a simple design. It required no thought whatsoever from the student and very little thought from the designer, provided the designer could read a good textbook on the subject and identify important technical terms and statements of principles from less important ones. And, in spite of all the evidence damning it (Anderson & Faust, 1967), it is a design that is still very much with us. Sometimes, as you can discover easily by checking the "programmed" section in some of the student workbooks that accompany mass market textbooks these days, it is still used in its antique unadulterated form. There are also variations on the design. The medium of presentation is one of its variable attributes. I recall a friend objecting to "taking dictation from a tape recorder," often with the assistance of a slide. You can use video if you have it. And, of course, a lecturer can write on a blackboard or overhead projector for students to copy into their notebooks. Other variable attributes render the design a little more subtle but nevertheless present. One can increase the amount of verbiage to be reproduced, moving from a fill-in test item to a whole essay. One can increase the interval between the presentation of the word and the request that the student reproduce the word. One can even provide an example or two of what is being talked about without overstepping the bounds, *provided* that the student is not required to decide whether the example is indeed one (Markle, 1978). The critical attributes of the model are that the student is told and then the student repeats back. Because the requirements that the student must meet are to remember and reproduce what was said, the error signals coming back to the designer during formative evaluation are relatively simple to handle. If the student forgets, give more practice.

Memorization is a distinguishable category in almost everyone's taxonomy, inside instructional development (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Gagné, 1965; Merrill, 1971) and outside. What Skinner (1957) called "intraverbals," Gagné (1972) "verbal information," or Tiemann and Markle (1978) "verbal repertoires" may be relatively complex behaviors involving organized knowledge and even paraphrasing of the original words, requiring instructional designs far more complicated than the filling-in-the-blank design. But these outcomes are still manipulations of words in ways that do not necessarily involve real understanding.

In a charmingly simple diagram, Faust (1977) recently suggested that design principles could be organized according to a 2 x 4 scheme for classifying objectives. Four basic kinds of content—facts, concepts, rules, and procedures—map onto two different kinds of behavior—remember and use. I am going to add one level to Faust's model, giving it an equally simple name in keeping with the others. The third level is "create," a rather ambiguous term that would include the wildest level of creativity as well as construction or discovery, under any level of guidance, of what others already know.

The model in Figure 1 is much simpler than elaborate models such as Guilford's

---

Author's Note. Paper presented at the symposium "Training Instructional Developers—Five Approaches," American Educational Research Association convention, April 1980.

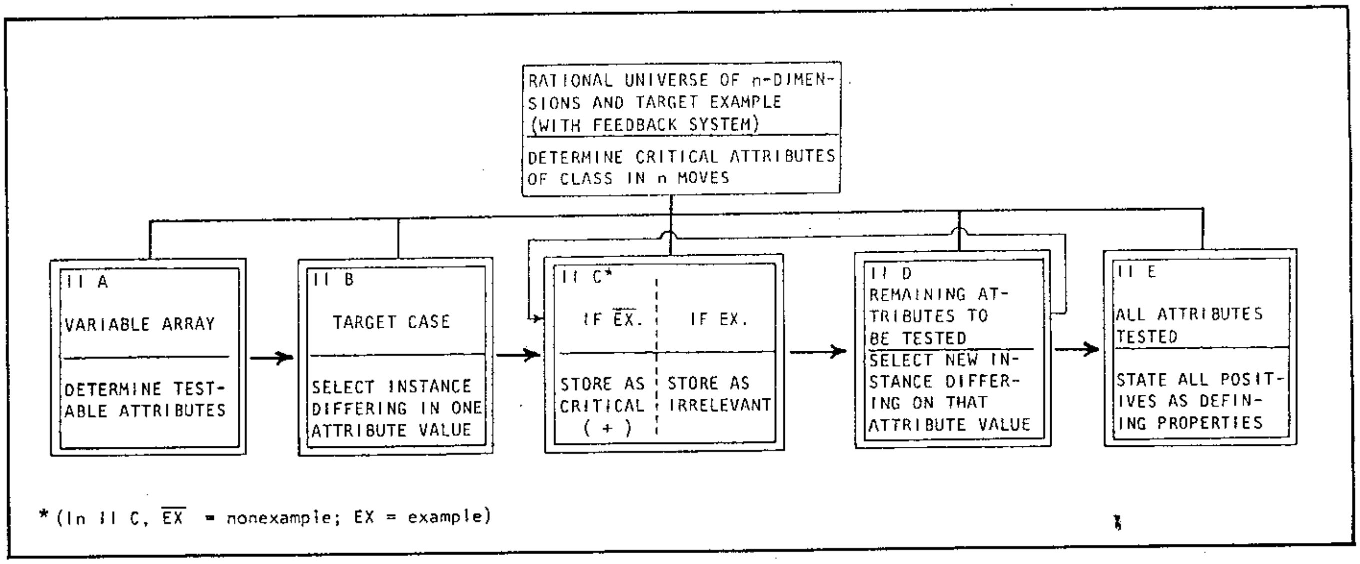


FIGURE 1. A content/behavior matrix (after Faust, 1977).

three-dimensional structure of intellect (1967) or Bloom's taxonomy, both of which had more categories of contents and behaviors. This model also differs from some of the taxonomies mentioned earlier because it provides a slot for remembering with respect to concepts and rules while others would restrict conceptual behavior to the "use" level. But it will do as an organizer to enable me to place instruction targeted toward thinking skills on its own separate level. The three levels have a certain degree of independence. I think we all agree that students may learn verbal information at the bottom level without being able to use it, and they may be able to use classification schemes without being able to verbalize the critical attributes or behave in rule-governed ways without being conscious of (i.e., verbalizing) the rules they follow. I'm not clear on how one could invent or discover a rule, however, without being about to use it, so the third level may imply the second level.

A bit of relevant ancient history is the 1960 paper by Evans, Homme, and Glaser (published 1962), describing their RULEG system for designing instruction in verbal subjects. It put instructional development squarely on the second level of Faust's diagram and constituted a significant improvement over the tell-them-and-have-them-fill-in-the-blank designs. The authors provided a clue to why we are primarily fixated on the second level: "Rather than run the risk of having the student induce an incorrect RU, it seems preferable to state the RU for him explicitly." In the past 20 years, most of the highly effective instructional products fall in this category. The sophistication of the appropriate designs is far beyond the simplistic RULEG formulas (Markle, 1978), but the learner's behavior remains equivalent to the outcomes implied in the early paper: Given a definition, the student classifies; given a rule, the student applies it; given a description or demonstration of a procedure, the student follows it.

Subject-matter experts at the forefront of their disciplines are operating at the "create" level. It strikes me that our real progress in instructional design has been in the increasing sophistication of the analysis processes required of designers. Designers also are operating squarely in the top row, even when the instruction they are to design is not at the forefront of the discipline. There is a reason for this. The RULEG authors may have believed that the rules were known and that it was, therefore, possible to state them explicitly for the students to apply. Most of us have discovered otherwise. The concept analysis procedure, for instance, sprang from the frustrations of attempting to get students to use conventional definitions to classify examples and nonexamples (Markle & Tiemann, 1969). When you ask students to *remember* the definition of a concept or to *recall* the correct classification of given examples (back to the bottom row), the feedback from trials with students provides no error signal about the adequacy of the definition. But ask students to classify wide ranging new examples, and the feedback often will indicate how bad most of the definitions are. The same can be said for rules and procedures. The breakthrough in analysis led to the development of algorithms and decision tables (Lewis & Horabin, 1977) that made explicit the underlying logic of the applications. The secrets and unstated assumptions that students gradually stumbled on through trial-and-error practice are now clarified by analysis. Similar creativity has been applied to cognitive tasks in the familiar design documents that show hierarchical task structures, associated with Gagné (White & Gagné, 1974) and with Resnick (Resnick, Wang, & Kaplan, 1973).

Landa's work (1976) falls in the same category of discovery. I'd like to use his amusing chapter title "He couldn't figure it out because he couldn't figure it out" as a motto for instructional developers. Landa coined that title to express the frustration of a geometry teacher who couldn't teach a student to prove theorems because the underlying thinking strategies were unknown to the teacher. We can presume the teacher could do them, but doing them does not mean that the doer can communicate what is going on inside the head. To restructure Landa's phrase, he—the student—couldn't solve the problem because he—the teacher—couldn't verbalize or demonstrate the cognitive procedures involved.

It is fashionable to call for more research, and certainly we don't know all there is to know about teaching problem solving skills. However there are some useful ideas floating around. Both in research and in practical applications, there is an emphasis on developing protocols of thinking processes—blow-by-blow descriptions of how the thinker is proceeding through the problem (Lochhead & Clement, 1979). Problems in college-level disciplines require a heavy component of knowledge along with the procedural skills required to think like a subject-matter expert. Also, for my particular students, who are experts in their disciplines, it is very hard to get the feel of the tentativeness of the thinking processes involved when they attempt to analyze problems they already know how to solve. So protocol practice begins on a wide variety of so-called "simple" problems where the prerequisite knowledge may be as simple as knowing the alphabet or knowing basic arithmetic facts, but the cognitive processes can be as complex as any in chemistry or physics. There are several rich lodes to be mined for anyone who wants to think about thinking, among them the Piagetian exercises from Renner's group (Renner, Stafford, Lawson, McKinnon, Friot, & Kellogg, 1976), the Guilford-based series by Samson (1975), the eclectic course materials from Whimbey and Lochhead (1979), and the creativity exercises of Parnes (1967), as well as brain twisters that research psychologists have been using for years.

A good example of the latter is the conservative focusing strategy from Bruner's classic research on concept formation (Bruner, Goodnow, & Austin, 1956). Recast into the analytic documentation modeled by Resnick and her associates (1973), the procedure for solving these problems is shown in Figure 2.

Data abound in the concept formation literature demonstrating that college students confronted with such problems do not exhibit such an organized attack on solving them. Although the domain of problems used in research studies may be of minimal interest to most science educators, it is not difficult to demonstrate that the steps in the strategy are basic to many problem solving procedures in many disciplines and to comprehension of many disciplines. With a few changes in the steps, the focusing strategy is directly parallel to the two different approaches to concept analysis of Markle and Tiemann (1969) and Becker, Engelmann, and Thomas (1975). With very few changes, the diagram can be reconstructed as a flowchart of the major Piagetian formal operation "manipulation and control of variables" tested (and found wanting in many students) by Renner and his associates (1976). A similar strategy is employed by a subject-matter expert in attempting to build a rational classification scheme in a not-yet-organized area of a discipline, where the attributes that will result in well-defined coordinate and superordinate relations are not the simple ones of color, shape, and numerosity of Bruner's early experiments.

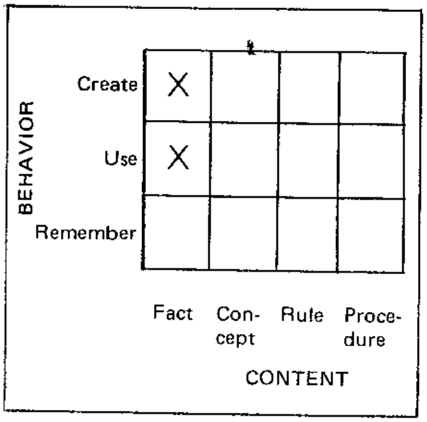
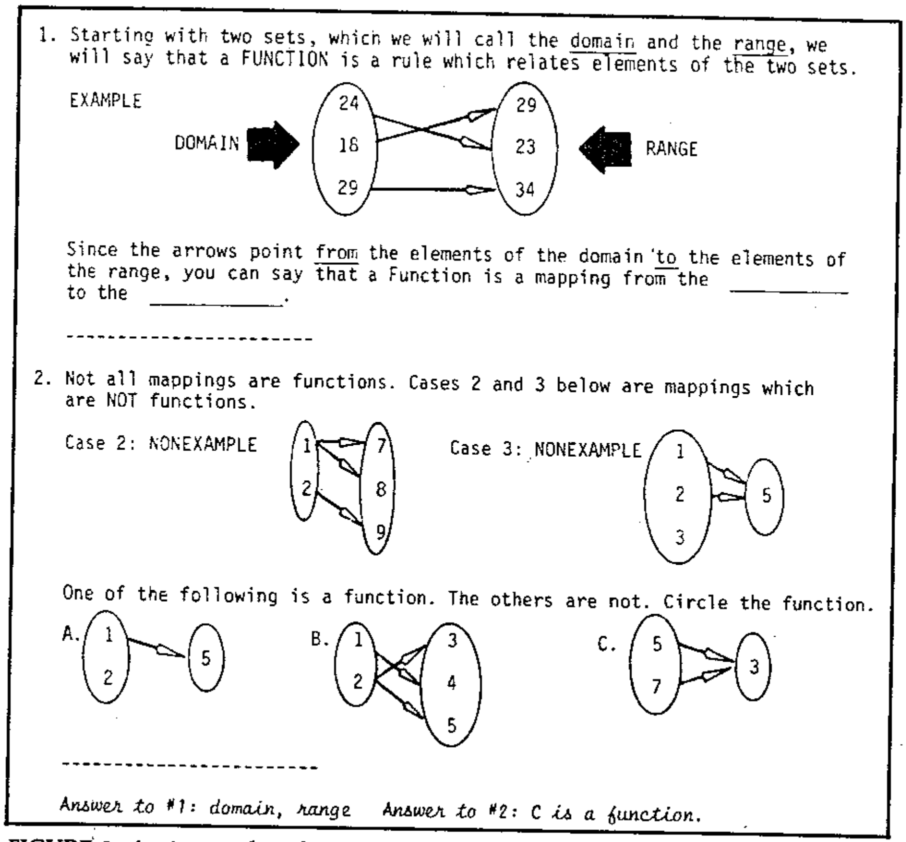


FIGURE 2. Procedural analysis of the conservative focusing strategy.



1. Starting with two sets, which we will call the domain and the range, we will say that a FUNCTION is a rule which relates elements of the two sets.

Since the arrows point from the elements of the domain to the elements of the range, you can say that a Function is a mapping from the ____________ to the ____________.

----

2. Not all mappings are functions. Cases 2 and 3 below are mappings which are NOT functions.

One of the following is a function. The others are not. Circle the function.

Answer to #1: domain, range   Answer to #2: C is a function.

FIGURE 3. An incomplete design for a level three concept problem (from *Designs for Designers*).

One of the demonstrable generalizations of this family of strategies is its applicability to "discovery" exercises of the sort shown in Figure 3. The exercise shown there was an erroneous design generated by one of my students that the present generation of students is required to repair (Markle, 1978, p. 151). To solve the problem correctly, learners must go through steps very similar to those in Figure 2. The error made by the designer lies in providing insufficient information for learners to complete the third step in the hypothesis-testing strategy, leading to a 50% error rate on the exercise.

The design for the "function" exercise, when done correctly, falls into the top level of Figure 1. The learner is required to generate hypotheses about potential attributes, test these against the information given, construct the correct rule, and apply it to the choices given. There is some evidence (cf. Egan & Greeno, 1973) that forcing the student to think through the classification scheme, as this design does, results in some deeper level of comprehension than do designs that verbalize the scheme and ask the student to apply it, in other words, designs at the "Use" level. Further research to tease out what else it might be that students learn when forced to construct rather than to receive knowledge certainly is needed. But, if the results hold up, the wisdom of many science educators who now exhort us to get the students to think through the subject matter rather than digest it will be vindicated.

At the moment, I would have to admit to a very qualified success in attempting to change the behavior of teachers towards greater emphasis on training students to think. In classroom exercises, my students can discriminate between exercises (or objectives) that fall at the third versus the second level of the content/behavior matrix. They can repair faulty exercises such as Figure 3 in simple subject matters, given data indicating that learners fall flat in trying to solve the problem. They can take a design in which the rule is stated and the learner is to apply it and turn the design into one in which the learner is to discover the regularity involved. But, if they *can* do all these things, will they? At the end of the course, each designer creates a product of whatever type would be most useful in his or her ongoing teaching situation. To date, almost none of these products has applied the design principles at the third level. Why?

I think there are two reasons for this. One is habit. "Instruction" conventionally involves a great deal of teacher talk. As the oldtimers in RULEG noted, human verbal behavior is so efficient that telling the student gets you there fast—if what you tell is true. All design students have had many years of experience with instruction as learners, and most of my students are experienced as instructors too. They know how it's done. Glad as they are to escape the memory level, the second level is comfortable and satisfying.

The second reason is the press of time, not just time to do the requisite analysis and design at the highest level, but the press to cover the discipline. For most instructional designers working within conventional colleges and universities, freedom to teach what one wishes in the way one wishes is not possible. Few young teachers have the political clout to throw out the department syllabus and the fat respectable textbook and to reorient their courses to where the students are in their cognitive development. No one has presented the case with more passion than Arons (1973) talking to his colleagues in physics: "If we are serious about cultivating some measure of . . . understanding . . . we must give the students time to learn; the pace must be slow enough to let them confront the evidence, to think and contemplate, to relive some of the steps by which the human mind first achieved these insights . . . . When I urge, as I do here . . . that we back off, slow up, 'cover' less, give students a chance to think and understand, someone invariably demurs: 'But if we stop way back here, if we do not cover our subject, students will never *know* about this . . . .' To this I can only respond that the demurral constitutes a terrible prostitution of the word 'know.'"

There is a small but increasingly voluble chorus across the country opposing the viselike grip of content coverage and calling for cognitive development—i.e., thinking—as *the* valuable outcome of liberal arts education. When we become the majority, instructional designers will have to be ready with the skills and models for reaching these important new objectives.

References

Anderson, R. C., & Faust, G. W. The effects of strong formal prompts in programed instruction. *American Educational Research Journal*, 1967, *4*, 345-352.

Arons, A. Toward wider public understanding of science. *American Journal of Physics*, 1973, *41*, 769-782.

Becker, W. C., Engelmann, S., & Thomas, D. R. *Teaching 2: Cognitive learning and instruction*. Chicago: Science Research Associates, 1975.

Bloom, B. S., Englehart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. *A taxonomy of educational objectives: Handbook I, Cognitive domain*. New York: David McKay, 1956.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. *A Study of Thinking*. New York: Wiley, 1956.

Egan, D. E., & Greeno, J. R. Acquiring cognitive structure by discovery and rule learning. *Journal of Educational Psychology*, 1973, *64*, 85-97.

Evans, J. L., Homme, L. E., & Glaser, R. The RULEG system for the construction of programmed verbal learning sequences. *Journal of Educational Research*, 1962, *55*, 513-518.

Faust, G. W. Selecting instructional strategies. *Journal of Instructional Development*, 1977, *1*, 18-22.

Gagné, R. M. *The conditions of learning*. New York: Holt, Rinehart & Winston, 1965.

Gagné, R. M. Domains of learning. *Interchange*, 1972, *3*, 1-8.

Guilford, J. P. *The nature of human intelligence*. New York: McGraw-Hill, 1967.

Landa, L. N. *Instructional regulation and control*. Englewood Cliffs, N. J.: Educational Technology Publications, 1976.

Lewis, B. N., & Horabin, I. S. Algorithmics 1967. *Improving Human Performance Quarterly*, 1977, *6*, 55-86.

Lochhead, J. & Clement, J. (Eds.) *Cognitive process instruction*. Philadelphia: Franklin Institute Press, 1979.

Markle, S. M. *Designs for designers*. Champaign, Ill.: Stipes, 1978.

Markle, S. M., & Tiemann, P. W. *Really understanding concepts: Or in frumious pursuit of the Jabberwock*, Champaign, Ill.: Stipes, 1969.

Merrill, M. D., (Ed.) *Instructional design: Readings*. Englewood Cliffs, N. J.: Prentice-Hall, 1971.

Parnes, S. J. *Creative behavior guidebook*. New York: Scribner's, 1967.

Renner, J. W., Stafford, D. G., Lawson, A. E., McKinnon, J. W., Friot, F. E., & Kellogg, D. H. *Research, teaching, and learning with the Piaget model*. Norman, Okla.: University of Oklahoma Press, 1976.

Resnick, L. B., Wang, M. C., & Kaplan, J. Task analysis in curriculum design: A hierarchically sequenced introductory mathematics curriculum. *Journal of Applied Behavior Analysis*, 1973, *6*, 679-709.

Samson, R. W. *Thinking skills*. Stamford, Conn.: Innovative Sciences, Inc., 1975.

Skinner, B. F. *Verbal behavior*. New York: Appleton-Centry-Crofts, 1957.

Tiemann, P. W., & Markle, S. M. *Analyzing instructional content: A guide to instruction and evaluation*. Champaign, Ill.: Stipes, 1978.

Whimbey, A., & Lochhead, J. *Problem solving and comprehension: A short course in analytic reasoning*. Philadelphia: Franklin Institute Press, 1979.

White, R. T., & Gagné, R. M. Past and future research on learning hierarchies. *Educational Psychologists*, 1974, *11*, 19-28.