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FROM BEHAVIOURISM TO COGNITIVE BEHAVIOURISM TO COGNITIVE DEVELOPMENT: STEPS IN THE EVOLUTION OF INSTRUCTIONAL DESIGN*

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ABSTRACT

The recent history of instructional technology is traced, starting with the work of Skinner, moving on to the task analytic approach of Gagné, and following through to contemporary efforts associated with the "cognitive revolution." It is suggested that an understanding of the process of cognitive development may enable us to build on and improve earlier approaches, by adapting them more directly to students' current levels of cognitive development, and by ensuring that we do not overtax their information processing capabilities. To illustrate and support this claim, a number of recent instructional studies are cited, some of which have utilized classic developmental tasks, and some of which have utilized conventional classroom material.

The cornerstone of behaviourist learning theory was the idea that behaviours are learned (become habitual) as a result of reinforcement. This idea was not sufficient to form the basis for an instructional technology, however, because it dealt with the strengthening of behaviours already in the repertoire of the learner, whereas the central concern of instructional technology is to promote new learning. Although the early behaviourist theories advanced by Watson and Thorndike were influental as a source of general principles that teachers might apply, it was mainly through the work of Skinner (1954) that a genuine behaviourist technology of instruction began to develop. The crucial concept that made an instructional technology possible was the concept of *shaping* or *successive approximations*. By reinforcing behavioural variations that were *in*

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the direction of the desired behaviour, Skinner suggested that it would be possible to modify the learner's existing behaviour so that, by degrees, it would be transformed into the desired novel behaviour.

Behaviourist instructional technology developed a wide range of techniques, but they were usually consistent with the following procedure:

0. Identify the potential reinforcers that are available and that are effective for the learner in question.
1. Identify and objectively describe the desired behaviour.
2. Describe the initial or "entering" behaviour of the learner.
3. Define a series of behaviours, starting with the entering behaviour and leading to the desired terminal behaviour, each successive behaviour representing a small modification of the preceding one.
4. Move students through the sequence of behaviours by use of demonstrations and instructions, coupled with positive reinforcement of behavioural variations that are of the desired direction.
5. Ensure, through reinforced practice, that each behaviour is thoroughly learned before advancing to the next step.

This general procedure introduces several principles that have continued to be valid as new technologies of instruction have emerged. The first is specification of objectives in terms of what the person *does* rather than in terms of what the person *achieves*. Thus, for instance, the objective is not a certain score on a multiplication test but rather the performance of certain actions that will lead to, among other things, a good score on a multiplication test. Behaviourist technology defined these actions solely in terms of observable behaviour, whereas more recent technologies have dealt with unobservable, mental actions, but the emphasis on process rather than product remains similar. Another principle is that instruction must take account of the learner's existing ways of doing things, rather than focusing simply on the ultimate behaviour to be achieved. As we shall see, this principle becomes even more prominent as we move toward an instructional technology that incorporates ideas drawn from developmental psychology. Finally, there is the principle of *intermediate forms* in learning. In order for the learner to move from one state of knowledge to another, there may need to be intermediate knowledge states that are specifically identified and pursued as sub-objectives. This important principle, too, is embodied in all subsequent technologies of instruction.

Behaviourist instructional technology had three major weaknesses, however. The first was that the principles of reinforcement, although obviously important in human learning, turned out to be less all-powerful than behaviourist learning theory had implied. Gagné (1963) reviewed a number of failures of behaviourist technology in military training applications. He concluded that in most training situations the key problem is identifying in sufficient detail *what* needs to be taught. Once this has been adequately determined, the problems of *how* to induce the desired changes in behaviour are usually minor. Since reinforcement techniques apply only to the *how* of instruction, rather than to the *what*, they cannot deal with the central problems of teaching.

This point leads directly to the other two weaknesses of behaviourist instructional technology. Because behaviourist theory dealt exclusively with observable behaviours, it provided an awkward, almost useless language for specifying objectives of school learning (Bereiter, 1968). For instance, in order to deal with an instructional objective such as understanding the concept of momentum, the behaviourist had to either translate this into the behavioural objective of reciting a certain definition of momentum, which degrades the objective into one of rote memorization, or else specify some application of the concept, which entails further requirements beyond understanding the concept. In practice, so-called behavioural objectives have often not really specified the behaviour that was intended to be taught (since that could not be done without using mentalistic terms). Instead they have specified tests to be applied, thus often misleading educators into focusing on the test rather on the instructional objective that the test was supposed to reflect.

The final, and most devastating weakness, however, was that behaviourist technology provided no methods for carrying out a key step in its own program – step 3 in the general procedure listed above. How does the educator identify behaviours that are steps in the direction of the desired terminal behaviour, and how does the educator determine that these steps are small enough that they can be successfully negotiated by the learner? To the strict behaviourist, these things could only be determined after the fact. In practice, behaviourist educators had to rely on conventional instructional wisdom for the design and sequencing of instructional steps.

Thus, although behaviourist technology made important contributions, which we have noted, it proved ultimately to be irrelevant to the design of instruction. Behaviourist technology is still being successfully applied in education, for instance, in the Behavioural Analysis Follow Through Model (Bock, Stebbins and Proper, Note 1). But in these applications it is essentially a technology for managing the classroom implementation of instructional programs that have been designed according to other technologies or according to no systematic technique at all.

To state it somewhat more formally, the central problem that emerged for instructional technology was not how to modify behaviour, but how to specify attainable sub-goals that would lead to the attainment of educational objectives. Behaviourist instructional technology, as we have seen, recognized this central problem but did not attempt to solve it. It did, however, create a foundation for later technologies that have tried to deal with the problem of specifying intermediate steps in instruction.

The next major advance in instructional technology came from the work of Gagné (1963, 1968). Although still working within the behaviourist tradition, Gagné managed to overcome the three weaknesses of behaviourist instructional technology that we noted above. First, he shifted the focus of attention from the *how* to the *what* of behaviour change: that is, he shifted the focus from reinforcement to the nature of the behaviours themselves. Second, he recognized a variety of types of learning, which included not only the learning of physical behaviours and simple stimulus–response connections but also the learning of concepts, rules, principles, intellectual skills, and cognitive strategies. Gagné gave special attention to the category of intellectual skills, which includes reading, writing, mathematical problem solving, and many other skills central to the purposes of schooling. He proposed that, in learning these skills, the most important thing was not reinforcement and practice but rather the systematic building of higher-level skills upon lower-level skills. This brings us to his third and most noted attempt to overcome the limitations of behavioural technology. He proposed a technology for identifying and sequencing intellectual skills so that instruction could progress systematically to build higher-order skills on the basis of intellectual skills already possessed by the learner.

Gagnés technology, known as hierarchical task analysis, grows out of the idea that any particular higher-order intellectual skill is based on several lower-order intellectual skills, that each of these is based on still lower-order skills, and so on. The resulting model of learning is consequently not a linear sequence of instructional goals but rather a branching network of subordinate skills. Gagné proposed that this network could be derived by starting with the highest level skill and asking what lower-level skills it presupposed. Applying this question repeatedly to lower-level skills would generate lower and lower levels of prerequisite skills until, finally, skills were specified that the learner already possessed. At that point, one had the framework necessary for designing an instructional program leading from the intellectual skills of the learner up to the top-level skill that was the objective of instruction.

The instructional technology based on this analytic approach may be summarized by the following general procedure:

1. Identify the intellectual skill that the instructional programme is intended to teach, and develop a measure to assess its presence.
2. Using the technique of hierarchical task analysis, identify successively lower-level skills until a level has been reached such that all students are expected to possess the skills on entry into the programme.
3. Develop assessment devices for each skill and subskill and use them to determine the individual child's entering competence.
4. Present instruction that progresses from the child's existing skills to skills at successively higher levels in the hierarchy.

5. Before beginning to teach any new skill, make sure that the student has mastered all the lower-level skills that it depends on.

Figure 1 illustrates a hierarchy of subskills leading up to the top-level skill of solving proportion problems algebraically. Notice that the lower-level skills are not successive approximations to the final skill. Instead, they are distinct skills in

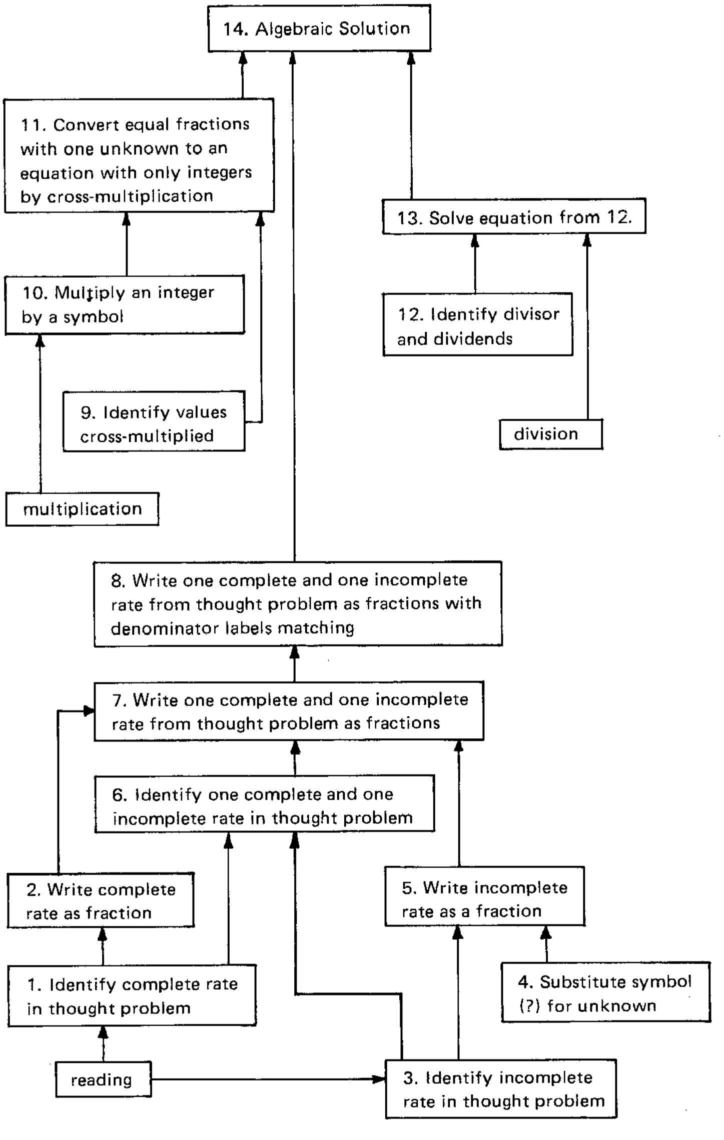

Fig. 1. Learning hierarchy diagram for algebraic proportion solution.

their own right that must ultimately be combined in order to achieve the top-level objective. The instructional program based on this hierarchy proved to be quite successful (Anderson, 1977; Gold, 1978).

With the transition from Skinner to Gagné, educational psychology and technology was in effect making a move from *behaviourism* to *cognitive behaviourism*: a move which was taken concurrently by most other branches of psychology in North America. As can be seen, this move involved a de-emphasis on elementary behaviour and reinforcement, and an increased emphasis on the complex mental entities and operations which intervene between a child's initial exposure to a complex task, and his ultimate mastery of it. As readers who are familiar with the psychological literature will be aware, this initial shift broadened into a complete revolution, with psychology becoming increasingly "cognitive" and decreasingly "behaviouristic" in the two decades from 1956 to 1976.

Having participated in the original dissatisfaction with early behaviourism, and having pointed to the direction of the new instructional psychology, Gagné continued to follow the direction of the cognitive revolution, eventually re-working his theory and his technological prescriptions so that they dealt less with tasks or skills, and more with internal processes. The basic nature of his educational suggestions, however, remained the same, and led to a considerable improvement in educational technology. Educators who adopted Gagné's approach no longer had to rely on previous instructional wisdom or convention in designing steps in instruction. They could apply a rational technique that took advantage of what they knew about the mental operations involved in task performance.

While the advantages which Gagné's approach provided were considerable, certain problems eventually began to surface. One of these was that the approach was occasionally unsuccessful (a) with young children or (b) with tasks that even adults find hard to understand. The above-mentioned study by Anderson provides an example of the former sort of difficulty. While the hierarchy was successful in teaching average grade seven students how to solve proportionality problems, it was *not* successful in teaching grade five students to solve the same problems, even though the grade five students who were trained were brighter, and appeared to have all the same prerequisities. Other studies conducted in our laboratory revealed similar difficulties either in teaching young children or in teaching adults. If the material was very difficult to begin with, it sometimes remained difficult, even after a learning hierarchy approach had been implemented (Case, 1968a, b). We therefore set about to diagnose the cause of these problems and to remedy them.

Our first hypothesis was that the problem must lie with the nature of the specific hierarchies which had been suggested: that certain specific components must have been left out of them, which would turn out to be critical for the population in question. In a series of clinical studies that we conducted, however, we found that this was not the case. The problems did not appear to stem from the omission of any critical specific component. Rather they appeared to stem from two sources that were quite different. Either (1) the number of components which the students had to consider in progressing through the hierarchy was beyond the limits of their working memory, or (2) the partial set of components that they *could* consider was misleading: that is, it suggested an incomplete strategy, which the subjects applied in the naive belief that it was adequate (Case, 1968a, b). Once these problems were diagnosed, two further lines of inquiry were pursued. The first was an attempt to determine the role that these same two factors played in human cognition and development in general. This led to an interest in Piaget's and Pascual-Leone's theories of development (Piaget, 1970; Pascual-Leone, 1970) and ultimately to a proposed modification of those theories (Case, 1978b; in press). The second line of inquiry was to determine how these difficulties could be circumvented, for a variety of developmental tasks. This led to a number of relatively specific suggestions (Case, 1975), and ultimately to a general technology of instruction that was, in effect, a modification of Gagné's. The basic elements of this technology were as follows.

1. Identify the task to be taught, and develop a measure for assessing students' success or failure on the task.
2. Diagnose the strategy which experts use for succeeding at this task.
3. Diagnose the strategy used by younger or less sophisticated subjects who fail the task.

4a. Design a paradigm for showing the children why their current strategy is inadequate, and for enabling them to assemble a more powerful one.

4b. Minimize the working memory load of the instructional program by (i) simplifying the structure of the successful strategy (if possible), and (ii) identifying a sequence of steps from the incorrect to the correct strategy, in such a fashion that the number of novel cues or operations at each step is reduced to a minimum.

5. Provide sufficient practice at each step that the operations already applied become automatic, thus further reducing the load on working memory.

In specifying this procedure, an attempt was in effect being made to move from an instructional technology that already took account of the complexities of human cognition, to one that also took into account its development. Two aspects of the technology reflected this transition. The first was that – in suggesting one look at error-producing strategies – it was being acknowledged that there was a "natural" organization and hierarchy to cognition, which a purely logical analysis could not reveal. The second was that – in suggesting that children would have to understand the deficiencies of their current procedure – it was being suggested that the process of instruction should in some sense recapitulate the process of development: that one could not expect a genuine understanding to emerge from the simple concatenation of a number of arbitrary parts.

The above general procedure was applied to the teaching of arithmetic word problems by Gold, with the following results.

1. Definition of task. The task children were to be taught was any word problem where it was indicated that $x/y = x'/y'$, and where three of the four quantities in question were given.

Four classes of problem were used as criterion tests. The first set was quite straight forward, and taken from arithmetic texts. The second three sets were more complex, and were taken from the developmental literature. Several example problems are indicated in Table I.

2 & 3. Strategy diagnosis. The strategy that is used by experts, and which the Anderson program had attempted to teach, is the cross multiplication method. The incorrect strategy that was used by beginners, as made clear by Piaget's work, involves subtraction or addition rather than ratio. Suppose, for example, that children are told that mixture A is four parts water to one part juice and asked how much water should be added to two parts juice to make it taste the same. Their natural tendency is to say "There were three more parts water the first time, so these should still be three more". The answer they give is therefore five.

4a. Paradigm creation. The paradigm that was designed for showing children the limitations of their own strategy, and the merits of the correct

TABLE I

Criterion Test

Problem type	Example	No. of problems
Varied word problem	I can cook 2 pies with 5 big apples. How many pies can I cook with $12^1/_2$ big apples?	5
Juice equivalence	I put 6 cans of water and 2 of lemonade in one pitcher. Then I put 18 cans of water in another pitcher. How much juice should I put in the second pitcher for the two mixtures to taste the same?	6
Juice concentration (from Noelting, 1975)	One pitcher has 4 water and 3 juice. The other has 5 water and 4 juice. Which tastes more "juicy"?	6
Mr. Short and Tall (from Karplus & Peterson, 1970)	Here is a picture of Mr. Short. He is 3 big paper clips tall. If I measure him with small paper clips, he is 6 tall. I have a taller man in my office who is 4 big paper clips tall. How tall will he be if I measure him with small paper clips?	3

TABLE II

Sequence of Activities for Ratio Word Problems

Level	Description of strategy	Example items	
1	Given a unitary ratio, can match it to supply the missing value	1/3 = 1/?	1/2 = ?/2
2	Given a unitary ratio, can iterate to find the missing value for a non-unitary ratio	1/2 = 3/?	1/3 = ?/9
3	Given an integral ratio, can reduce to unitary ratio, then iterate to find the missing value for a non-unitary ratio	3/6 = 2/?	2/4 = ?/10
4	Given a non-integral ratio, can reduce to a unitary ratio and iterate to find the missing value for a non-unitary ratio	2/3 = 3/?	2/3 = ?/9

strategy, was one involving packages of bubble gum, with the same number of pieces in each. Physical props were used so that, when children used addition as a method, they could actually pair up the gum and boxes and see that their method did not work. After children had finished the bubble gum exercise, they were then given a parallel set involving juice and water.

4b. Reduction of working memory load. Working memory load was reduced in three fashions (1) by teaching the children a successful strategy that was structurally simpler than the cross multiplication method, namely the unitary method (2) by sequencing problems in such a fashion that only one new feature was introduced at a time, as is shown in Table II and (3) by providing subjects with extensive practice at any one level, before proceeding to the next.

Two groups of students were used to test the program. Students in the one group were "math disabled" and were in grades six and seven. Students in the other group were normal, and were in grades four and five. Neither of the groups could pass the criterion test at the outset. Using a criterion of 65 percent success, the rates indicated in Table III were obtained on a one month delayed posttest.

TABLE III

Percentage of Children Passing Posttest (Criterion: 65 percent of Items Correct). Number of Children Per Cell = 9

Population	Method		
	Cognitive development (%)	Cognitive behaviourism (%)	Standard school curriculum (%)
Normal	100	78	33
Math-disabled	100	33	11

The conclusion that was drawn from these results, and others like them, was that the developmentally-based approach to instruction involved a clear advantage over traditional approaches, and at least a modest improvement over approaches based on cognitive behaviourism – particularly for populations who find the material in question particularly difficult. The details of the developmental approach were therefore spelled out, as an aid to curriculum designers (Case, 1978a).

In the six years since this article was published, three different lines of inquiry have been pursued in an attempt to extend the approach still further, and to clarify it.

1. Isolating the Key Feature of the Developmental Approach

The first line of inquiry has been experimental, and devoted to isolating the key features of the developmental approach: that is, the features that are responsible for its effectiveness. This work has been conducted in collaboration with our doctoral students.

In discussing his results in the word problem experiment, Gold suggested that five different factors might have combined to make the programme as successful as it was. These were (1) the use of intuitively meaningful and familiar situations (i.e., the gum and box problems, and the juice and water problems) (2) the use of manipulative aids, (3) the use of "progressive elaboration" as a teaching method: that is, the introduction of simple word problems in the first exercise, followed by the addition of one and only one new problem feature in each subsequent exercise, (4) the targetting of the first exercise to the subjects' incorrect strategies, and (5) the teaching of a correct strategy that is simpler than that used by experts: that is, the "unitary" strategy. In order to follow up on these suggestions, Dennis (1981) conducted a study in which the first three of these factors were manipulated experimentally. This was done by creating variants of Gold's programme in which one feature was altered, and comparing the performance to an unaltered or "control" programme. In *Group 1*, the feature that was altered was the meaningfulness of the problems presented. Students were given problems involving *X*'s and *Y*'s and *P*'s and *R*'s, instead of gum and boxes and juice and water. In *Group 2*, the feature that was altered was the presence of manipulative aids. In this group the standard problems devised by Gold were used, but no manipulative aids were presented. Instead, children were shown pictures of gum and boxes and juice and water. Finally, in *Group 3*, the feature that was altered was the use of progressive elaboration. The first three levels of Gold's programme were omitted (i.e., the levels that gradually built up problem complexity). Instead, students were introduced to the highest level first, and given more practice so that the total number of problems that they encountered was the same as in the Gold programme. A total of 40 fifth graders participated in the study, ten in each of the four groups.

The results of the study were surprising but informative. There was some suggestion that the third experimental group found the initial instruction the most difficult. They appeared to experience considerable confusion as a result of encountering the complex problems first, and took significantly longer to complete the gum and boxes problems than did the control group. By the end of the training programme, however, this difference had disappeared. Thus, on the twelve day delayed posttest, there was no significant difference between this group and the control group. Of even greater interest was the fact that there was no difference between any of the other groups and the control group either: not only on the posttest, but during the training as well. In discussing her results, Dennis therefore concurred with Gold, who had suggested that the most important factor of the five he enumerated was very probably the use of the unitary method. One further consideration supports this conclusion. On studies that have looked at the spontaneous development of children's approaches to arithmetic word problems, it has been shown that – well into the ninth grade – students who are successful do not use the expert cross-multiplication strategy, even if they have been explicitly taught it. Rather, they use the unitary strategy. A variety of ratio or cross-multiplication strategies eventually emerge, but not until about grade twelve (Gajewski, Note 2). It would appear, then, that the instructional method which was selected was in fact developmentally more appropriate. A further improvement still, and a matching to young children's spontaneous addition strategies, may have been achieved by using iterative addition instead of multiplication in introducing the method.

On the assumption that the above line of reasoning is correct, one can suggest a further expansion of the developmental technology, as follows:

1. Identify the task to be taught and develop a measure for assessing students' success or failure on it.
2. Develop a procedure for assessing the strategy subjects employ on the measure.
3. Use this procedure to assess the strategies used by children at a variety of ages, both those where success is not achieved by current methods, and those where it is.

4a. Devise an instructional sequence for "recapitulating development," i.e., for bringing students from one level to the next, in course of the instruction.

4b. Keep the working memory load at each step within reasonable limits.

5. Once children's performance at one level becomes relatively automatic, move on to the next.

2. Probing the Range of Tasks for Which the Developmental Approach is Appropriate

A second line of inquiry has been devoted to probing the range of tasks and populations for which the developmental method of instructional design may be appropriate. This has not been done in experimental studies, but rather in clinical ones. The general procedure has been to select individual children who are having some difficulty in a particular school subject, and to see if a significant improvement can be made in their performance by applying the developmental method. To date, successful clinical studies of this sort have been conducted on the following specific tasks.

Missing Addend and Subtrahend Problems. Here the most common incorrect strategy is to perform the operation indicated by the sign, (i.e., $5 + \mathbf{13} = 8$) without any attention to the position of the missing value. The most common successful strategy pays attention to the position of the missing element, but uses a counting procedure rather than a sign reversal procedure for getting the right answer. A variety of paradigms has been shown to be capable of bridging the gap between these two strategies once they are identified, in a relatively short period of time (Gold, 1978; Lam, Note 3).

Two Digit Addition. Here the most common incorrect strategy involves an irregular procedure in carrying, although more idiosyncratic strategies such as adding all the digits (e.g., $25 + 31 = 11$) have also been identified (Stober, Note 4). The correct strategy is the same as that used by experts, but appears to involve a more explicit representation of the base ten operations that are involved. Our successes here have all involved making this sort of representation more explicit.

Adding Positive and Negative Numbers. Here the most common incorrect strategy is to assume that two negatives always make a positive e.g., $-5 + -7 = +12$. The correct strategy used by novices involves a concrete representation, and a directional counting strategy. This is acquired with some ease by students who are failing, once it is taught explicitly (Hammil, Note 5).

Long Division. No one incorrect strategy has been found here. The situation appears closer to that described by Brown and Burton (1978) for multiple digit subtraction. Children may invent a variety of specific sub-routines, to compensate for some particular aspect of the general routine which they either apply incorrectly, or have no representation for at all. Once the particular problem is diagnosed, remediation by developmental methods appears to be effective (Taylor, Note 6a).

Addition of Fractions. One erroneous strategy that we have looked at in this area is the addition of both numerator and denominator (e.g., $\frac{1}{2} + \frac{1}{4} = \frac{2}{6}$). The instruction we have found successful has involved the establishment of a concrete referent for each fraction, and the working of examples in both symbolic and concrete form. (Stevens, Note 6b; Kamo, Note 6c).

B. LANGUAGE ARTS

The strategies that are used by experts in the area of language have not been subjected to as much detailed analysis as those involved in mathematics. Nevertheless, they appear to be equally regular, as do the incorrect strategies used by novices. So far, we have looked at the following tasks.

Discriminating letters. Letter discrimination is a process which is not executed by a strategy that flows through time, but by attention to a set of critical features which is then processed in parallel. Nevertheless, children's errors are similar to those observed on other tasks, in that they stem from an incomplete utilization of the same feature set as that noticed by successful students. Once one is aware of which features students can represent already, and those which they can not, instruction can proceed quite rapidly (Baines, Note 7a; Lau, Note 7b).

Sounding Out words. A developmental sequence of word attack strategies has been identified by Marsh (1980). Moreover, children who have particular problems have been shown to "fixate" at level 1 or level 2, rather than to progress spontaneously. Once the nature of their current functioning is understood, developmental progress can be produced with relative ease. (Skillen, Note 8; McKeough, Note 9).

Spelling. Although spelling is often thought of as a rote task, much of it proceeds in the same fashion as does other linguistic processing, namely by the application of general rules about linguistic structure. In two studies that we conducted, the incorrect strategies which children were applying were somewhat idiosyncratic, although sensible in their own right. Once the incorrect strategy was diagnosed, transition to the "expert" strategy followed quite simply (e.g., Ammon, Note 10; Rebick, Note 11).

Reading for Meaning. Reading for meaning is a high level task that involves flexible application of a variety of strategies. However, it is clear that a developmental hierarchy of strategies exists, and that students who have difficulty tend to be those who adopt a very low level strategy, namely attending to individual sentences and topics rather than to the structured message (Geva, 1980; Scardamalia and Bereiter, in press).

Once students are made aware of their current strategy, and the difference between it and that used by experts, considerable progress can be achieved (Case and Fry, 1971; Church, Note 12; Blasczekiewitz, Note 13; Bird, 1980).

Written composition. Writing also depends on flexible application of a large number of strategies. This makes it difficult to produce a general upgrading in the way students write. When particular strategies are focused on, however, we have found it possible to move students toward more expert strategies in composition planning (Scardamalia and Bereiter, 1980), revision (Bereiter and Scardamalia, 1982; Cattani, Scardamalia and Bereiter, 1982), and theme development (Paris, Scardamalia and Bereiter, 1982).

C. SOCIAL STUDIES

As yet, the developmental approach has not been applied very systematically in this area. One study has been conducted, however, that might serve as a possible model. In this study, a group of children's spontaneous strategies for utilizing concepts of longitude and latitude were identified, and the instruction successfully modified on this basis (Halliday, Note 14).

D. PHYSICAL EDUCATION

Although space does not permit a detailed account of the studies we have conducted here, suffice it to say that the approach appears highly applicable. We have had success in indetifying incorrect strategies in shoe-tying with a preschooler, ball-catching with an elementary school child, and the forehand stroke in tennis and volleying in volleyball with adolescents. In all cases, we have also experienced success with our instruction. (Elliott, Note 15; Bebense, Note 16; Prince, Note 17; Ives, Note 18; Nailer, Note 19).

E. LIFE SKILLS

A final area that has proved amenable to this sort of analysis has been the sort of critical life skill which is normally acquired spontaneously, but which must be taught explicitly with the retarded, or with young children who for some reason or another wish to master it at a younger age than normal. The skills that we have examined in this area are time telling (Cummings, Note 20; Steinbach, Note 21; Sandieson, Note 22; progress), and making change with money (Hayakawa, Note 23).

3. Improving our Conception of Development, and Its Relationship to Instruction

If the key feature of the developmental approach is the teaching of a strategy that "fits" the child's current level of intellectual development, in a fashion that does not over-tax his powers of working memory, then it becomes of considerable importance to improve our conceptualization of how children develop, of how this development is limited by working memory, and of why some strategies constitute a better "fit" to a particular developmental level than others. Our third line of inquiry has been devoted to attaining these objectives. A detailed summary of this work will shortly be available (Case, in press). For the moment, however, two points are worth mentioning.

1. THE ROLE OF PROBLEM REPRESENTATIONS

It turns out that, if one is to provide a reasonable characterization of children's intellectual development, it is vital that one describe the way in which they represent particular classes of problems, as well as the strategies that they employ. In fact, it would appear that the particular strategy which is employed can normally only be understood once the child's problem representation is understood, since the strategy flows quite directly from this representation. This being the case, it becomes of considerable educational importance to be able to describe children's representations, and to know how to design paradigms or examples that are compatible with them. In fact, the clinical successes we have had with the developmental method may stem in large part from the fact that the method has been employed by skillful educators, who have been able to do this intuitively. That is, they have been able to use their diagnosis of incorrect strategies, and of the correct strategies used by novices, as a clue to understanding the way in which children spontaneously represent the task in question. Having made this leap, they may then have drawn on their intuitions further to create an instructional paradigm that is congruent with this representation. What we hope ultimately to be able to do, then, is provide a more formal way of approaching this part of the educational planning process, and guidance for those who do not spontaneously engage in it.

2. THE ROLE OF PROBLEM GOALS

It also turns out that, if children's intellectual development is to be characterized in any sort of complete fashion, it is vital to describe the way in which they represent the goals of particular tasks as well. In fact, one way of defining a strategy is as a method of bridging the gap between the representation of a current situation, and the representation of a desired situation, or goal. This being the case, it becomes of considerable educational importance to present paradigms whose goals can be comprehended at children's current level of functioning and which can be expanded and modified, rather than simply abandoned, as the instruction progresses. This may be another important way in which a developmental method of instruction differs from a learning hierarchy method, namely that it strives for some sort of global representation of the ultimate task goal at even the lowest level of the hierarchy, rather than switching from one goal to another at different levels, and introducing the ultimate goal only at the top level. A test of the importance of this design feature is currently underway (Sandieson, Note 22). The hypothesis that underlies the test is that poor transfer of learning from the classroom to the outside world, or from one problem class to another, often results from the fact that one counts on children using a similar strategy in two situations, simply because the situation is defined in a similar way in each case. If transfer is truly to be optimized, however, it may be that children must spontaneously construe the goals of the two situations in the same way as well.

The general line of thinking that underlies both the theoretical questions we are pursuing may be summarized as follows. Mental structures are tripartite entities, involving the representation of a current situation, the representation of a desired situation, and a strategy for bridging the gap between the two. The developmental procedure of identifying an incorrect and a correct strategy, and of designing instruction on this basis, may be effective because it focuses on the most visible aspect of these tripartite structures: the tip of the iceberg, as it were. However, if individuals who have not had a great deal of experience in teaching or in working with young children are to apply the method successfully, it may be necessary to be explicit about how to reconstruct the part of the iceberg which is below the surface. The most successful educational planners at the moment, it seems to us, are those who can perform this task intuitively, and enter the mental life of the child as a natural part of the planning process.

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