THEORY OF INSTRUCTION:

Principles and Applications

By Siegfried Engelmann and Douglas Carnine

Revised edition

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Foreword, 1991 Edition

by Robert Dixon

Many questions regarding Theory of Instruction: Principles and Applications have arisen in the years since the publication of the first edition in 1982. Is it a textbook? Why wasn't it named, Theory of DIRECT Instruction? Why is it so difficult to read? How relevant is it to the current Zeitgeist of educational philosophy? And last-and least-is the cover of the 1982 edition red or orange?

I propose at this publication of the revised edition, that Theory of Instruction is exactly what the title implies, and further that my proposition is of potentially inestimable significance to the field of education.

Theory

First and foremost, Theory of Instruction is the articulation of a theory-not in the atheoretical sense “theory” is used in educational jargon, but in the more precise sense well-established among scientists and philosophers of science.

Engelmann and Carnine's theory evolved the same way original natural science theories have evolved, through the scrupulous application of logical analysis to existing empirical observation. The Engelmann and Carnine theory possesses the most critical attributes of natural science theories: (1) it is exhaustive in that it covers everything from the most basic motor skill instruction to the highest of the “higher order” thinking skills, and (2) it does so economically. In short, it is parsimonious.

Engelmann and Carnine's theory builds logically from just two initial assumptions: that learners perceive qualities, and that they generalize upon the basis of sameness of qualities. (This is not unlike the way Euclidean geometry derives logically from a minimum of unproven and unproveable assumptions about points and lines.) If we accept Engelmann and Carnine's simple assumptions and if we were to employ rigorous logic to any instructional problem, then the instruction we would derive would fall within the constraints of the Engelmann and Carnine theory. We wouldn't come up with the same instruction, but rather, with the same or similar instructional principles.

That is highly significant. Engelmann and Carnine don't look at the book when they develop instruction; they developed most of their instruction before they wrote their book. They haven't memorized various sequences from their own book, either. They simply apply the logic of their own theory to new content, and essentially recreate manifestations of their theory. Put another way, one very good indication that Engelmann and Carnine are operating within the framework of a theory is that they are constrained to adhere to their own theory. One can only religiously conform to a theory that exists. It strikes me as absolutely fantastic that the published Direct Instruction programs—before or after the theory book—are consistent in terms of how examples of given types are ordered and sequenced. (Some variation exists due directly to refinements in the theory.) Absolutely no other published programs of any type demonstrate such consistency, at such a level of detail. Absolutely no other published programs have an underlying, consistent rationale for the examples they use and the order they use them in. It's quite likely that few
authors of published educational materials have ever given the slightest thought to the fact that when we change the examples, we change the information that is communicated to the learner.

The Engelmann and Carnine theory provides a basis for making predictions that can be tested. In the absence of a theory, experimentation is driven by random hypotheses based upon “plausible ideas” or intellectual frolicking. If such hypotheses prove to be false, little is gained, save the rejection of one of an infinite set of plausible (but wrong) ideas. If such hypotheses prove to be true, very little is still gained: there's an idea that shows promise, but where does it fit? How does it relate to other ideas that show promise? The current state-of-the-art in educational experimentation is characterized by this kind of tinkering with plausibility.

If a hypothesis generated by a theory proves false, on the other hand, not only is the hypothesis itself questionable, but because of the logical interconnectedness of the theory's components, the entire theory becomes questionable. But if a hypothesis generated by a theory is verified, then the veracity of the entire theory is strengthened. Theory-based research is worth the time and effort; plausible idea-based theory isn't. When Time charged that the longest running joke on most university campuses is the Education Department, the black humor tended to obfuscate the reason that so many non-education academics might feel that way: conducting research in the absence of a theory might be funny, were it not for the unconscionable waste of money and human resources.

A true theory not only predicts, but explains. For example, if we are interested in why cognitive psychologists have, after several years of research, concluded that the extent to which learning transfers is dependent upon the relative salience of surface and structural features of examples, this theory will explain that for us. If we are interested in why a typical textbook presentation of a new concept must fail to communicate accurately to many learners, this theory will explain that, too.

Instruction

Theory of Instruction, again as the name implies, is a theory of instruction, not a theory of learning. Learning theories (if they are really theories at all) are no doubt of value to those interested in how humans learn in the absence of instruction (which generally is inefficiently).

Theory of (DIRECT) Instruction

There is a relatively simple fact about the Engelmann and Carnine theory that many educators appear to find disturbing: it is the only theory of instruction and therefore, does not require the "direct" qualifier. Although we hear of all kinds of “theories” of learning and even a few “theories” of instruction, this book represents the only theory of instruction that would withstand the rigorous tests of theories required by philosophers of science—disciplined logical interconnectedness, predictive value, parsimony, etc.

Theory of Instruction does not prescribe any “one best way,” but rather, describes a range of best ways, and suggests an infinite range of ineffective ways. (If I were to set out to intentionally design the worst instruction possible, I would still look to Theory of Instruction for guidance on how to precisely lead students far astray.)

I have even heard serious educational researchers express the fear that if Theory of Instruction is the first and only theory of instruction, then there would be nothing left for anyone else to do. That is like arguing that Newton's Principia and Lavoisier's Chemistry killed physics and chemistry. The emergence of a first theory in a field opens that field to countless opportunities for inquiry, closing off only those practices akin to changing lead to gold. (Geocentrism died because it was untrue,
not because it was unpopular.)

Reading the Theory

I've never heard of anyone who found Theory of Instruction to be an easy read. In general, any written theory, in the presence of either no competing theory or no similar theory, will be hard to read. The reader will not possess a frame of reference necessary for easy comprehension. That's one way of characterizing the purpose of a theory: to create a new frame of reference. I doubt that Principia was anyone's leisure reading when it first appeared.

Engelmann and Carnine's Theory of Instruction is as clear as it can be for whom I believe to be the principal intended audience: Engelmann and Carnine. Imagine carrying around in your head a theory so exhaustive, so economical, on a subject so broad and complicated. My conjecture is that a crucial stage in the development of any true theory is for that theory to be written down, first and foremost for the benefit of the theorist(s), and then only secondarily for any of the rest of us who might be interested. The theory seems complex because it is complex.

Summary

Theory of Instruction could easily be the most important educational book ever written, bar none. (Yes, I am aware of Aristotle and Dewey and Piaget and Skinner, etc.) Instruction is at the heart of education, and Theory of Instruction is the first true theory that cuts to the heart of instruction. Although I believe the theory of instruction to be fundamentally correct, even that judgment is secondary to the importance of a theory existing in the field of instruction. My contentions herein may seem like exorbitant fanaticism. Time and experience will tell.

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Introduction, 2016 Edition

What is Instruction?
The words instruction and teaching do not occur very often in the education literature. In fact, the word instruction appeared only 18 times in the 230 pages of the Common Core standards. The words teach or teaching appeared only 5 times. Ironically, instruction or teaching is what is supposed to occur in the classroom. Specifically, if the learners do not have a particular skill or bit of knowledge, the assumption is that the learners will acquire these through some form of “interaction” or process in the classroom. The interaction or process that is designed to transmit skill or knowledge is teaching. It may be disguised as a “learning activity” and may be configured so the teacher has no role in directly transmitting a specific skill or information, but instead does something that is designed to change the learner’s cognition in specific ways. Practically and pragmatically, whatever the teacher does that is supposed to result in specific changes in the learner’s repertoire and behavior is “teaching.”

In a rational system, teaching is related to three other processes—standards, curriculum, and testing. The four processes occur in a fixed order that starts with standards and ends with testing.

The order is justified on rational grounds. The sequence couldn’t start with teaching without specifying what to teach and how what is taught is related to other skills and knowledge that are scheduled for students to learn. Logically the curriculum and standards must be in place before specific teaching occurs. Without these prerequisite processes there would be no safeguards against first-grade teachers presenting material that is neither appropriate for the subject being taught nor for the grade level. Standards:

If the curriculum is math level K or 1, a possible appropriate standard would indicate that learners are to “Count backward from 20 to 0.” The standard, “use information from the text to draw conclusions about where Columbus would go next” is more advanced (possibly grade 4 or 5) and is not a math standard but a geography, history, or science standard. Curriculum:

The standards imply specific features of the curriculum. If a skill or informational item is specified in a standard, there necessarily must be a specific segment of the curriculum that provides the instruction needed to teach the skill or information. If this provision is not honored, there would be no rational basis for relating the standards to the curriculum.

A proper curriculum scrupulously details both the order of things that are to be taught and the requirements for adequate or appropriate teaching.

The curriculum is often packaged as an instructional program. A properly developed curriculum would have detailed “lesson plans” that provide adequate directions for the sequence and content of what is to be presented first, next, and next in each successive lesson.

The degree to which the teacher’s presentation behavior is specified by a lesson script varies greatly across programs, but the goal of all instructional programs is the same—to provide students with the skills and information specified by the standards.

Questions about the adequacy of the teacher presentation are answered empirically, by facts about student performance. If the teacher presents lesson material the way it is specified, and students learn the skills and content, whatever training and scripting the program provided are judged to be adequate. Conversely, if students tend to fail, the presentation the teacher provided is flawed. It may require observations to determine why it failed and what has to change for the teacher to be successful. Note, however, that it is not possible to observe the presentation in one part of the program and extrapolate to unobserved portions of the program. A program could
have parts that are quite good with respect to teaching students, and have other parts that are quite bad. Teaching:

Teaching is the process that follows the specifications provided by the curriculum. The relationship is simple: the teaching must transmit to the students all the new skills and knowledge specified in the curriculum. A test of a valid curriculum would show that students did not have specific knowledge and skills before the teacher taught them. The posttest that is presented after instruction shows that students uniformly have the skills. The conclusion is that a process occurred between the pretest and posttest and caused the specific changes in student performance.

The evaluation of a curriculum that occurs when a high percentage of students fail the posttest is more complicated. The failure could have been caused by a flawed curriculum, by flawed standards, by a flawed presentation, or by a combination of flawed curriculum, standards, and presentation. If the grade-one standards have items that assume skills that are not usually taught until grade 4 or 5, the teacher fails when she tries to teach her first graders these skills, and the students fail the test items that require these skills.

It is not possible to look at the outcome data alone and infer why the failure of these items occurred. We have to analyze what knowledge and skills students would need to pass these items, and identify the instructional sequence that would be needed to teach this information and skill set. Testing:

The final process is testing. Its purpose is to document the extent to which the student performance meets the standard. Also the testing should be designed to disclose information about each standard. As noted above, if students fail items on the pretest and pass items of the same type on the posttest, we assume that teaching accounted for the change in performance.

Ideally the testing would occur shortly after students have completed the teaching. The testing should be fair and extensive enough to generate specific information about the standards, the curriculum, and the teaching.

Standards that are unreasonably difficult or inadequately taught are identified by examining test results of the highest-performing classrooms. Any items that are failed by more than half of the students are possibly poor items or items that test material that is poorly taught. The most direct way to obtain more specific information about the failed content is to work with students who failed specific items and observe what they tend to do wrong or what information they don’t know.

Benefits of Theory of Instruction

Instruction is the essential operation that drives standards, curriculum, and assessment. Instruction provides the basic evidence of what can be achieved in altering student performance. These facts of achievement, in turn, provide the basic foundation for standards, curricula, and testing. The problem with current instructional practices is that there are no widely accepted rules for what instruction is capable of achieving or of the essential details of successful instruction.

This paucity of information occurs because there are no widely accepted guidelines for using facts about teaching to formulate standards or assessments. Stated differently, there is no widely recognized theory of instruction that lays out basic principals of teaching and that provides various empirical tests to facilitate refinement of instructional practices.

Theory of Instruction fills this gap. It articulates principles of effective instruction in sufficient detail to permit educational practitioners to develop effective instruction. The effectiveness of the
instruction may be measured by comparing results generated by Theory of Instruction with results of other educational approaches.

A final implication is that if educational institutions have clear information about the extent to which students of all levels can be accelerated, the institutions are then able to develop and install reasonable standards, effective curricula, and fair assessments.

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Overview of Strategies

Section I provides the theoretical foundations for the analysis of cognitive skills and the implications that are derived therefrom for how to teach those skills.

The precise analysis of cognitive learning is difficult, if not elusive, because it stands at the juncture of three separate analyses—the analysis of behavior, the analysis of stimuli used as teaching communications, and the analysis of knowledge systems or the content to be taught. (See Figure I.1) The analysis of behavior seeks empirically-based principles that tell what is universally true about the ways in which the environment influences behavior for different classes of learners. The analysis of communications seeks principles for the logical design of communications that effectively transmit knowledge. These principles allow one to describe the range of generalizations that should logically occur when the learner receives specific sets of examples. The analysis of communications focuses on the ways in which examples are the same and how they differ. The analysis of knowledge systems is concerned with logically organizing knowledge so that relatively efficient communications are possible for related knowledge.

The analysis that has received the most attention from psychological theories is the analysis of behavior (Hilgard & Bower, 1975). Although the other two analyses have received some theoretical attention (e.g. Gagne, 1970; Bloom, 1956; Markle & Tiemann, 1974), there has been little systematic effort to develop precise principles of communications used in instruction or to analyze knowledge systems. This book frames behavior theory within a three-way analysis of human cognitive learning.

The three areas of analysis derive directly from the nature of cognitive learning. The first aspect of cognitive learning is that the learner learns from the environment, which means that the environment is somehow capable of communicating concepts or skills to the learner. The analysis of communications provides rules for designing these communications so they are effective transmitters.

Another aspect of cognitive learning is that it always involves some topic or content. When we think, we think about something, even if that something is a process. This aspect of cognitive knowledge carries basic implications for designing the communications that we present to the learner. We cannot communicate with the learner without communicating something. Conversely, if we are to understand how to communicate a particular bit of knowledge (such as knowledge of the color red, or knowledge about the operation of square root), we must understand the essential features of the particular concept that we are attempting to convey. Only if we understand what it is and how it differs from related concepts can we design a communication that effectively conveys the concept to the learner.

The final aspect of cognitive learning has to do with the relationship of a given concept to other concepts. The word large is related to the word blue because both function as adjectives. The color blue is related to the color red because both have the properties of color. The relatedness of cognitive knowledge suggests that it is possible to develop a classification system for various types of knowledge (circle 3 in Figure I.1). If this classification system is to be of value to the instructional designer, the system should be designed so that the classification of a particular skill carries information about how to communicate that skill to a learner. Concepts that are structurally the same in some respects can be processed through communications that are the same in some respects.

Both the analysis of communications and the analysis of knowledge systems are logical analyses.
that involve assumptions about the learner. The analysis of behavior, however, investigates the learner and how the learner responds to specific communications. Chapter 1 presents an overview of the strategy that we will use to unite the three parts of the analysis; Chapter 2 further develops the analysis of communications; Chapter 3 outlines the organization of knowledge types that will be used throughout the book.

**Theoretical Foundations**

A theory of instruction begins with the assumption that the environment is the primary variable in accounting for what the learner learns. The different skills learned by people in different environments suggest that the assumption is reasonable. People who live in primitive societies learn skills quite different from those learned by people who live in urban societies. Although the environment is assumed to be the primary cause of what is learned, it is not assumed to be the total cause. Within any group of people there are individual differences. Also, there are differences that correlate with the age of the learner. Therefore, the learner is also a variable.

To show the relationship between the role of the environment and the learner, we are faced with the basic problem of experimental control. We must control one of these variables (the environment or the learner) before we can make precise observations about the other variable. Ideally, we would rule out or eliminate one of these variables (either the environment or the learner) and observe the remaining variable in a pure state. This solution is not possible. A possible solution is to control one of the variables so that it functioned as if it were ruled out. We cannot readily achieve such control over the learner because we do not know precisely how to do it. However, such control is possible with the environment. We can design communications that are, ideally, faultless. Faultless communications are designed to convey only one interpretation. From a logical standpoint, these communications would be capable of teaching any learner the intended concept or skill. When we present such a communication to the learner, we effectively rule out the environment as a variable. The communication is not merely standardized; it is analytically or logically capable of transmitting the concept or skill to any learner who possesses certain minimal attributes discussed later. The learner either responds to the faultless communication by learning the intended concept, or the learner fails to learn the intended concept. In either case, the learner's performance is framed as the dependent variable. The extent to which the learner's performance deviates from the performance that would occur if the learner responded perfectly to the communication provides us with precise information about the learner. The deviations indicate the extent to which the learner is not a perfect “mirror” of the environment. Furthermore, these deviations are caused by the learner (not the environment, which has been controlled so that it is faultless).

The strategy of making the communication faultless and then observing the performance of the learner is the basis for the theory of instructions that we will develop. We will use this strategy in designing instructional sequences and in deriving principles for communicating with the learner. The following is a summary of the steps in our strategy, showing where logical analysis is used and where behavior analysis comes into play:

1. Design communications that are faultless using a logical analysis of the stimuli, not a behavioral analysis of the learner.
2. Predict that the learner will learn the concept conveyed by the faultless presentation. If the communication is logically flawless and if the learner has the capacity to respond to the logic of the presentation, the learner will learn the concept conveyed by the communication.
3. Present the communication to the learner and observe whether the learner actually learns the intended concept or whether the learner has trouble. This information (derived from a behavioral analysis) shows the extent to
which the learner does or does not possess the mechanisms necessary to respond to the faultless presentation of the concept. Design instruction for the unsuccessful learner that will modify the learner's capacity to respond to the faultless presentation. This instruction is not based on a logical analysis of the communication, but on a behavior analysis of the learner.

Note that the behavioral analysis comes into play only after the communication has been designed so that it is faultless. The faultless presentation rules out the possibility that the learner's inability to respond appropriately to the presentation, or to generalize in the predicted way, is caused by a flawed communication rather than by learner characteristics.

Assumptions About the Learner

The primary problem that we face in pursuing this strategy is that we do not know what constitutes a faultless communication unless we make some assumptions about the learner. Stated differently, assumptions about the learner and the communication vary together. The greater the assumed capabilities of the learner, the less the assumed responsibility of the communication. If we assume that the learner will learn from any exposure to the environment, we will provide communications that do not control details of the presentation. If we assume that the learner is not capable of learning from communications that are ambiguous, we will approach the design of communications quite differently. To provide for control of the maximum number of communication variables, we must postulate a simple learning mechanism. Also, we must assume that the learner's behavior is lawful, which means the learner who possesses the assumed mechanism will learn what the communication demonstrates or teaches.

The learning mechanism that we postulate has two attributes: The capacity to learn any quality that is exemplified through examples (from the quality of redness to the quality of inconsistency). The capacity to generalize to new examples on the basis of sameness of quality (and only on the basis of sameness).

These attributes suggest the capacities that we would have to build into a computer that functions the way a human does. Note that we are not asserting that these are the only attributes that a human possesses, merely that by assuming the two attributes we can account for nearly all observed cognitive behavior.

The Capacity to Learn Any Quality from Examples

This assumption indicates what the mechanism is capable of learning, not how it learns. A quality is any irreducible feature of the example. The simplest way to identify qualities is to begin with a concrete example. Any example (such as a pencil) has thousands of qualities, which relate to shape, position, parts, color, texture, etc. All differences between a given concrete example and any other concrete example are differences in quality. Also, anything we do to change the example we start with is a change in quality. We can make the pencil shorter, break the point, paint it, change its position, and so forth. Each change is related to a quality of the original example.

The assumption that the learner mechanism learns qualities means simply that if an example possesses a quality, no matter how subtle, the mechanism has the capacity to learn that quality. The only factor that limits the learner mechanism is the acuity of the sensory mechanism that receives information about qualities. This mechanism, however, is capable of learning qualities as subtle as the unique tone of a particular violin or qualities that involve the correlation of events (such as the relationship of events on the sun to weather on the earth).

The Capacity to Generalize on the Basis of Sameness of Quality

Attribute 1 above indicates what the learner is capable of learning. Attribute 2 suggests how learning occurs. According to this attribute, the learning mechanism somehow “makes up a rule” that indicates which qualities are common to the set of examples presented to teach a concept. By
using this rule, the mechanism classifies new examples as either positive examples of the concept or negative examples. A new example is positive if it has the same quality(ies) possessed by all the positive examples presented earlier. It is a negative example if it does not have the same quality(ies).

According to the assumption about the generalization attribute, there is no sharp line between initial learning and generalization. The rule-construction of the learning mechanism is assumed to begin as soon as examples are presented. In formulating a rule, the mechanism does nothing more than “note” sameness of quality. Once the mechanism “has determined” what is the same about the examples of a particular concept, generalization occurs. The only possible basis for generalization is sameness of quality. If the example to which the learner is to generalize is not the same as the earlier examples with respect to specific qualities it is impossible for generalization to occur unless the learning mechanism is empowered with magical properties.

A further implication of attribute 2 is that the generalizations the learning mechanism achieves are completely explained in terms of the examples presented to the learner and the qualities that are common to these examples.

Table 1.1 illustrates how the learning of conservation of substance is the same as the learning of red.

Both concepts are learned in the same way—through a communication from the environment that shows the nature of the concept. The only difference is what is learned. And the “whatness” is the quality that comes from the examples, not the learner. For the learner to learn these diversely different qualities, the learner must have the ability to detect both the quality of redness and the quality common to the conservation examples (e.g., the relationship between changes in appearance and changes in amount).

The Structural Basis for Generalization

The assumptions about the two-attribute learning mechanism imply the type of structure that we must provide to cause specific generalizations. The two-attribute learning mechanism suggests that the learner operates on qualities and sameness, and that both the qualities and samenesses come from the concrete examples that have the same quality and provide information that these concrete examples are the same in a relevant way.

The most general implication of the two-attribute mechanism is the nature of the analysis that we must use for cognitive learning. If the only primary difference between such disparate cognitive skills as learning the color red and learning conservation of substance is the quality that is to be learned, and if the quality comes from concrete examples (and not from the learner), the primary analysis of cognitive learning must be an analysis of qualities of examples and of the communications that present these qualities to the learner. This analysis focuses on the stimuli that the learner receives. We refer to this analysis as the stimulus-locus analysis (which is developed further in this and subsequent chapters).

More specific implications of the two-attribute learning mechanisms suggest the general parameters of a communication that is capable of inducing a particular generalization. This communication must meet these structural conditions: The set of positive examples presented through the communication must possess one and only one distinguishing quality. If we assume that the learner learns qualities that are presented through examples, we must make sure that the set of examples presented demonstrates only one identifiable sameness in quality—not
more than one. If every positive example in the set that is presented to the learner possesses two distinct qualities, at least two distinct generalizations are implied by the communication. Since one of these generalizations is inappropriate, the set of examples does not meet the structural conditions necessary for inducing the intended generalization. For instance, if every example of red presented to the learner was a circle and every example that was not-red was box-shaped, at least two generalizations are implied by the same communication. Possibly the learner will generalize according to sameness in shape (calling any circle “red” regardless of shape). Both generalizations are possible because both are based on the qualities and samenesses shown by the demonstration examples. Since a given learner is assumed to have no preknowledge of the concept and must base the generalization solely on the quality and sameness of demonstrated examples, a given learner may learn an inappropriate generalization from the demonstration of red circles.

To avoid this problem, we must eliminate the inappropriate quality from the demonstration examples. Different techniques are possible for achieving this goal; however, the simplest is to modify the set of examples so that some of the examples identified by the teacher as “not red” are circles. With this modification, the set does not present circularity as a distinguishing quality of the positive examples. The communication must also provide a signal that accompanies each example that has the quality to be generalized. This signal is the only means we have for treating examples in the same way. When we present examples that are physically different (such as two examples of red that are not the same shade) we must use some form of signal to tell the learner, in effect, that these examples are the same and that the learner must discover how they are the same. The signal, typically a behavior such as saying “red” for all examples that are red, also provides the learner with a basis for communicating with us. The learner can use the same signal, “red,” to let us know which generalization examples have the quality of redness.

The assumption about the signal accompanying the various examples is necessary because our goal is to induce a particular generalization. However, if we simply present a group of examples that share a particular quality, we cannot guarantee that: (a) the learner will attend to the common quality; or (b) we will be able to communicate about this quality, even if the learner does attend to it. For instance, if we present a group of objects that are red, how do we know that the learner is attending to the sameness in the quality these examples share? We face other problems if we wish to test the learner to see if the generalization was induced. How does the learner indicate which generalization examples have the quality? Unless we use some signal to suggest sameness (such as putting all red objects in one place or calling them “red” or associating some other unique signal with each example), we cannot demonstrate sameness; we cannot test sameness; and we cannot correct the learner who responds inappropriately.

For the most basic type of communication, two signals are implied. One is used for examples that have the quality. Another is used for examples that do not have the quality. The communication must present a range of examples that show the physical variation of the examples that exhibit a common quality. If every example that the communication presents to the learner is exactly the same shade of red, the communication does not provide adequate information about the range of variation in the quality that is to be labeled as “red.” Since this demonstration does not imply that other shades of red share the quality of redness, the communication is incapable of inducing the appropriate generalization to examples of other shades of red.

To show the quality that is to be generalized, the communication must demonstrate (through examples) the range of variation that typifies the concept. In other words, the communication must present positive examples that are physically different, but that share the quality that is to be generalized.

The requirement of showing a range of positive variation derives directly from our assumptions
about the learning mechanism. We assume that the learner is capable of learning any quality exemplified through examples. For most concepts, the quality is something that is common to variations that are physically different. We assume that the learner has the capacity to make up a “rule” about this range of variation. We further assume that if we do not show an appropriate range of variation, the learner is not provided with the information that is necessary to formulate the appropriate “rule.” Therefore, if the communication fails to demonstrate the range, the learner cannot be expected to generalize appropriately. A basic communication must present negative examples to show the limits of the variation in quality that is permissible for a given concept. If we show the learner a range of red examples that differ in shades of redness, the communication may appropriately induce a generalization to new examples that are red. (The learner with the two-attribute learning mechanism should appropriately classify any example that falls within the demonstrated range of variation as “red.”) However, this communication does not show the boundaries for the generalization, which means that on a test of generalization, the learner may call pink examples “red.”

To show the learner basic concepts, the communication must demonstrate the boundaries for the range of permissible generalization. All negatives presented to demonstrate the limits of permissible variation are the same in that they possess the quality of being “not red.” To signal that these negative examples are the same, a common behavior is presented with each example. To assure that the learner does not classify these examples in the same way that the positive examples are classified, the communication presents a different signal for the negatives (for example, “not red”). The basic communication, therefore, presents two sets of examples (one for the positives and one for the negatives) and two distinct signals (one to signal each positive and the other to signal each negative). The communication must provide a test to assure that the learner has received the information provided by the communication. The test should present positive examples and negative examples that had not been demonstrated earlier, but that are implied by the range of variation of quality demonstrated for the positives and the negatives. If the learner has formulated an appropriate “rule” for the quality that had been demonstrated through the demonstration examples, the learner should be able to respond appropriately to new examples that fall within the range of variation previously demonstrated. A variation of the same signals that are used to demonstrate positive and negative examples is used when the generalization examples are tested.

In summary, the two-attribute learning mechanism implies that a communication for basic concepts must meet these structural requirements. The communication must present a set of examples that are the same with respect to one and only one distinguishing quality (the quality that is to serve as the basis for generalization). The communication must provide two signals—one for every example that possesses the quality that is to be generalized, the second to signal every example that does not have this quality. The communication must demonstrate a range of variation for the positive examples (to induce a rule that is appropriate for classifying new examples on the basis of sameness). The communication must show the limits of permissible variation by presenting negative examples. The communication must provide a test of generalization that involves new examples that fall within the range of quality variation demonstrated earlier.

Analyzing Whether Communications are Faultless

In addition to serving as guidelines for creating faultless communications, the five points above provide the basis for analyzing communications to determine whether they are faultless. The primary analysis for the communication involves no reference to a particular learner. The analysis does not deal with empirical information, but with the structural basis for generalization that is provided by the communication. A communication is judged faultless if it meets the five structural requirements outlined above. The set of examples presented to the learner must be unambiguous
about the quality that is to be generalized. The examples must be designed so that only one quality is unique to all positive examples. The range of positive variation exemplified by the set of demonstration examples must be sufficient to imply the appropriate generalization. The negatives should be precise in demonstrating the boundaries of a permissible generalization. The signals presented with the examples must unambiguously provide the basis for classifying examples as either positives or negatives. The test of generalization that is presented as part of the communication must assure that the learner appropriately responds to new positive and negative examples that are clearly implied by the set of demonstration examples. In summary, the communication is judged faultless if it adequately provides the learner with information about quality and sameness.

The structural requirements that must be met if a communication is to be judged faultless do not refer to specific techniques that are used to correct an inappropriate communication or to design one efficiently. However, these techniques (which are discussed in later chapters) follow from the structural requirements. If we understand that a communication must show that a particular quality is unique to the positive examples, we will investigate possible techniques that achieve this goal. From the possibilities we will select those that are most efficient and those that show the uniqueness most emphatically. Similarly, the design of the test examples can be reduced to some how-to-do-it formula once we understand what the test examples must do.

The five structural requirements derive directly from our assumptions about the learner. We can appreciate the implications of the two-attribute learning mechanism by considering how the structural basis for a generalization would change if we changed our assumptions about the learning mechanism. For instance, if we assumed that the learner generalized on the basis of similarity, not sameness, we would not be provided with a strict standard about whether the communication that we design presents examples that are “similar.” The notion of similarity is not precise and it begs the question of how the “similar” examples are the same. If examples are similar, they must be the same with respect to some quality, but the notion of similarity does not require us to identify this qualitative sameness. Therefore, similarity leads to an imprecise standard for evaluating our communication. By assuming that the learner generalizes only on the basis of sameness, we are required to create examples that are the same in some identifiable way, and the standard we use is objectively stronger.

If we assumed that the learner’s generalizations are not clearly determined by the common quality of the concrete examples of a concept, we would not be provided with a standard for judging whether a communication adequately shows both the quality and the range of variation in the quality across various examples. We might assume that the generalization would occur simply if the learner received some “exposure” to the concept. But we would not have any analytical yardsticks for determining whether the “exposure” presented through a particular communication was adequate.

With the assumed two-attribute learning mechanism, however, we are provided both with general guidelines for creating structures that will induce specific generalizations, and with more specific implications about what the communication must do and what it must avoid doing.

Predictions of Generalizations

The procedure for determining flaws in a communication is a logical one, based on observable details of the communication. The procedure therefore permits us to make predictions about what the learner will learn. These predictions are independent of the learner. The basic form that these predictions take is that if the communication is flawless (adequately meets the five structural requirements), the learner will learn the generalization that is conveyed through the communication. The learner will respond appropriately to the examples that test the
generalization and will respond to additional examples that are implied by the demonstration examples. Conversely, if the communication has flaws, some learners who receive this communication will learn the inappropriate quality demonstrated by the flawed aspect of the communication.

Equally important, the development of procedures for determining whether a communication is faultless permits us to engage in a very precise study of the learner. A faultless communication serves as a standard against which we compare the learner's performance. If this communication is analytically faultless (with respect to clarity in communicating one and only one possible generalization), any learner who possesses the two-attribute learning mechanism will learn the concept that is presented by the communication. If a learner does not perform in the predicted manner, we immediately know three things about that learner: we know that the learner does not have (or is not using) the two-attribute mechanism. We know the precise ways that the learner's performance deviated from the predicted performance. Because we know that the problem resides with the learner and not with the communication (which is judged faultless), and because we know precisely how the learner has deviated from the predicted standard, we know how we must modify the learner so that the learner is capable of performing acceptably in response to the communication.

We are able to make these strong inferences about the learner because we have ruled out the possibility that the learner's poor performance can be accounted for by the presentation. Furthermore (as we observed earlier), we would not be able to draw precise conclusions about the learner unless we ruled out the possibility that the communication has flaws and that the learner is responding in a logically reasonable way to the flawed communication. If the learner generalized to circles following the communication that presented circularity as a quality common to all positive examples of red, we would be presumptuous if we interpreted this generalization as an indication of a "faulty" learning mechanism. Only if the communication is faultless can we make strong inferences about the learner.

Stimulus-Locus and Response-Locus Analyses

Although the major goal of this book is to describe procedures for designing effective instructional communications, not to study the learner's behavior, the procedure that we use parallels the one that we would use to study the learner. We use two analyses. The primary analysis is a stimulus-locus analysis, which deals with an analysis of the stimuli or communications the learner receives. The second analysis is the response-locus analysis, which focuses on the learner. This analysis comes into play if the learner is unable (for whatever reason) to produce the responses that are called for by the communication. The response-locus analysis consists of techniques for modifying the learner's capacity to produce responses. If the learner does not respond in the predicted manner to a faultless communication, the assumed "fault" lies not with the communication, but with the learner. Therefore, we must switch our focus. This switch involves a complete change in orientation, from a concern with the analyses of communicating quality and sameness in a precise manner, to the laws of behavior. These laws provide us with specific guides about the amount of practice, the massing and distribution of trials, the schedules of reinforcement, and other variables that cause the growth or strengthening of the learner's response to take place. For example, if the learner apparently forgets the word red and cannot respond to various examples in a faultless presentation that asks the learner, "What color is this?", we modify the learner's capacity to "remember" how to produce the name. When the learner reliably remembers the words, we return to the original communication. The learner is now assumed to be an adequate receiver, capable of responding according to the predictions of the stimulus-locus analysis.

The basic difference between the response-locus analysis and the stimulus-locus analysis is that
the stimulus-locus analysis does not involve the learner. It involves the logic of ruling out all the possibilities but the one to be conveyed through a teaching communication. The response-locus analysis is based on empirical findings on learning.

When instruction in skills involves teaching new responses (those the learner has never produced before in response to any signal), we use the stimulus-locus analysis to design the sequence of skills to minimize possible conceptual confusion. We also use response-locus techniques to assure that the new responses are induced efficiently. However, even for the teaching of “motor skills” (such as shoe-tying, ball-throwing, etc.), the stimulus-locus analysis is the primary one. The reason is that the communications must be clear and must be organized so that the appropriate generalizations are induced and the appropriate response generalizations are implied. These communications, however, rely heavily on the application of behavioral principles.

Extending the Stimulus-Locus Analysis to Types of Knowledge

If we follow the stimulus-locus assumptions to their conclusion, we discover that knowledge may be classified according to the samenesses of communications used to teach various concepts. The samenesses in features of the communication parallel samenesses in the concepts that are to be taught. Viewed differently, the extent to which concepts are the same provides a precise measure of the extent to which faultless communications for these concepts may have the same features or attributes. Let’s say that we design a faultless presentation for a particular concept. The communication isolates the quality presented to the learner, unambiguously signals the quality through examples, and provides additional examples for testing the learner’s generalizations. To design a faultless communication for a concept that is highly similar to the original one, we would create a communication that is highly similar to the original one. The close logical parallel between the structure of the concepts we wish to teach and the structure of the communications that convey these concepts faultlessly results because the two concepts are the same with respect to many qualities. The samenesses in quality of the concepts is reflected in the samenesses in the communications that convey these qualities. Conversely, if two concepts differ in many ways, the faultless communications that communicate them will have many differences.

By extending the notion of the parallel between the structure of concepts and the structure of communications that convey them faultlessly, we are provided with general guidelines for creating classes of cognitive skills. For this classification, each category consists of concepts or skills that are the same with respect to important structural features. Since the concepts in each category share samenesses, all concepts within a given category can be processed through simple variations or transformations of the same basic communication or form. To classify a concept within this system is to be provided with an algorithm for communicating the concept to a learner who is assumed to possess the two-attribute learning mechanism.

Summary

The design and analysis of communications are based on assumptions about the kind of information the learner is capable of extracting from the communication. For analytical purposes, we postulated a learning mechanism that has these attributes: the capacity to learn any stimulus quality shown through examples, and the capacity to generalize a sameness of quality to new examples. This assumed mechanism implies that the primary analysis of cognitive learning must focus on quality and sameness of the examples presented to the learner. Further implications suggest the structural criteria that must be met by a communication if the communication is to induce a generalization for a basic concept. The positive examples of the concept must be distinguished by one and only one quality. An unambiguous signal must accompany each positive example, and a different signal must accompany each negative example. The examples must demonstrate the range of variation to which the learner will be expected to generalize.
Negative examples must clearly show the boundaries of permissible positive variation. Test examples, different from those presented to demonstrate the concept, assure that the generalization has occurred.

These criteria serve as guidelines for designing faultless communications and for determining whether a particular communication is faultless. The analysis of communications according to the structural features of the communication is the stimulus-locus analysis. The stimulus-locus analysis assumes that the learner is a “receiver” capable of attending to the information presented through a “faultless” communication. However, a particular learner may not learn in the predicted manner. The difference between the learner’s actual performance and that predicted by the stimulus-locus analysis suggests the extent to which the learner does not respond to the basic logic of the communication (the logic of quality and sameness). If the learner is incapable of producing responses that are implied by the stimulus-locus analysis, our focus shifts from the stimulus-locus analysis to the response-locus analysis. Behavioral principles are used to induce new responses and to maintain responses.

Analysis of Basic Communications

This chapter describes basic communications, elaborates the procedures by which sameness and difference are conveyed to the learner, and outlines a new type of diagnosis of learning failure that is implied by stimulus-locus analysis.

Basic Communications

Basic communications play a very important role in a theory of instruction. They are the simplest forms that are used to communicate concepts. More elaborate forms are extensions of basic communications.

A communication occurs when the learner is presented with examples and verbal descriptions that demonstrate how to respond to particular stimuli. For the stimulus-locus analysis, the most basic communications are those that deal with generalizations. A non-generalization item, such as the task, “What's your name?” is perhaps more adequately viewed through a response-locus analysis. Even this task becomes involved in a generalization when the learner must discriminate who is to respond when “What is your name?” is presented to different people.

The most basic communication for the stimulus-locus analysis has the following features: A set of examples or instances. Some behavioral signal provided by the teacher with each example.

The set of examples consists of the things or events shown to the learner. All positive examples of the concept within a set have the quality that is being taught.

The behavior signal demonstrates whether a particular example has the quality. The signal may be complicated or simple. In the simplest form, the teacher uses two behaviors, the first for signaling, “Yes, this example has the features you are to attend to.” The other behavior signals, “No, this example does not have the features.” Any two behaviors can be used to communicate information about the “yes-no” classification of the examples in the set.

Any sameness shared by all examples that are treated in the same way describes a generalization.
If the examples treated in the same way share quality A and if the learner has the capacity to abstract this sameness, the learner will generalize to examples that have quality A.

If we hand a toddler a crayon and say, “Red,” then present another crayon and say, “Red,” we are asserting that there is something the same about both examples. If there were no structural sameness in the object, we would have no basis for treating them in the same way. By treating things the same way, we do not guarantee that we communicate how they are the same. We merely signal that something about the situations is the same. Perhaps the act of receiving a crayon is “red;” perhaps the act of coloring is “red;” perhaps anything you can scribble with is “red.” All possibilities are suggested by the communication above, because both examples that were treated the same way share these structural features.

This list of facts in Table 2.1 shows some “samenesses” possessed by both examples. The samenesses are the possible bases for generalizations.

The last column shows that many samenesses are logically implied by the communication. Which will the learner select? The answer is beyond the stimulus-locus analysis. We do not assume that the child has any preknowledge of the appropriate sameness. We therefore assume that the possibilities are “equal.” We might modify this conclusion on the basis of empirical information of how learners respond.

Learning Sets

We might further modify our conclusion on the basis of what the learner has learned in the past. For example, if the presentation above has immediately followed the successful teaching of green, yellow, and blue, there would be very little doubt that the presentation would teach red.

The reason, however, is that the teacher is treating various objects in the same way. If coordinate objects in group 1 have a particular color (green), and coordinate objects in group 2 have a particular color (yellow), then coordinate objects in group 3 have a particular color (red).

This is a rather sophisticated extension of the sameness application. The idea is basically simple. The learner is prompted to attend to a particular set of features because the previous communications have shown that these features are the basis for the preceding discriminations. The present communication involves examples that have many of the same visual properties the preceding communications had. The present communication also involves teacher behavior that has many of the same features as the behavior presented with the earlier communications.

Research on “learning sets” (Harlow, 1959) has shown that learners tend to learn faster or better on subsequent examples of the same type (e.g., oddity problems). The process can be explained by referring to what is the same about the various examples and the behavior used to signal them. Puzzles of a given type have solution features that are the same. By learning to respond successfully to different puzzles, the learner learns how to treat the puzzles in that same way. Therefore, subsequent puzzles involve less new learning than initial puzzles. The learner has learned to process the later puzzles through the same strategy steps that led to solutions with the earlier puzzles.

Tests of Generalization

The stimulus-locus approach treats generalizations as the product of the communication.
Samenesses, which form the structural basis for generalization, are shown through the communication. The learner will select one of the generalizations communicated. For us to determine whether this selection has occurred, we must test the learner. The simplest test is to present the learner with examples and see if the learner treats each in the appropriate manner. If we deal with a very simple communication (one that uses a “yes” signal for some examples and a “no” signal for others), we would present the learner with new examples that share a particular sameness with the examples identified earlier as “yes” and new examples that share the sameness with examples identified as “no.” From the learner’s pattern of responses we can determine whether or not the learner has learned a particular sameness. Note that the new examples we present may be physically different from the examples presented during the communication with the learner so long as they clearly possess a sameness shared by all the “yes” examples or by all the “no” examples.

The tests of generalization are limited to certain objective facets of the communication. We do not assume, however, that the communication conveys only these samenesses. If the receiver of the communication is capable of learning samenesses that are intentionally shown by the communication, the learner is also capable of learning many other “associations.” The teacher’s green dress may be the same as someone’s dress in a past situation of some import; the sound that occurs in the background may be the same as sounds in other learning situations. These “associations” will certainly occur. For instructional design purposes, however, we do not deal with these generalizations because we are unable to control them. No matter how carefully we control the ambient aspects of the learning situation, many uncontrolled generalizations will be possible.

Basic Concepts and Examples

A basic concept is one that cannot be fully described with other words (other than synonyms). A communication for a basic concept, therefore, is one that requires concrete examples. We cannot explain red to a blind person in a way that would permit the person to discriminate between red and not-red objects. Similarly, concepts such as smooth, heavy, over, toward, happy, etc., require concrete examples unless the learner already knows the concept by a different label (unrough, unlight, above, closer, glad). Examples are needed to teach these concepts because the words that we use are not containers of the concept. They are merely symbols that stand for particular qualities. Unless the communication presents the learner with the actual experience of the quality being symbolized, the communication provides no basis for understanding which quality or property the symbol represents.

A problem with concepts and their analysis is their potential confusion with words. A basic concept is not a word and does not logically imply words. The qualities (the samenesses that exist in sets of examples) are “real” and objective. The words used to refer to them are creations. These creations are useful if they serve their primary functions of signaling the quality. They may have a secondary function of fitting into grammar and possibly possessing features that are shared by other words that refer to similar events. (The word sixty is related to the word six because both have a common part and that part refers to a common feature of reality.) But the word is not the concept and does not imply the concept to a naive person.

Inducing Patterns of Responses

If we used only one word for each quality we would have no problem with words. The fact that one word has many possible meanings, however, suggests that if we begin with the analysis of words, we may become so embroiled in word games that we fail to observe that this approach is irrelevant. We should begin with the idea (basic sensory concept) that we wish to teach, not the word. Here’s how we could test an idea. We simply test the learner’s response pattern by requiring
the learner to point to different examples that show a concept. For instance, after instruction, we could tell the learner: “Point to all the objects that are over the table.” The pattern of responses for pointing does not require the learner to use words. However, the pattern shows the generalization. The same pattern would be observed if we substituted a verbal response for the pointing response.

If the question presented with each example is, “Is this object over the table?” the learner would say, “Yes” for every object that had been touched and “No” for every example not touched. If we tell the learner, “Tell me ‘over’ or ‘not-over,’” the learner would say, “Over,” for every object previously touched. If the same examples are responded to in one way when we require pointing to objects, when we require the learner to say “Yes,” and when we require the learner to say “Over,” something must be the same about those objects. If the only observable sameness is the quality of being over, we conclude that: (1) we have induced this quality or idea; and (2) the idea does not depend on any particular response. (The pattern of responses remains stable over different responses.)

The words that we use are merely signals for the qualities of examples. We make no assumption that teaching the particular meanings signaled by over will induce the understanding of over when it is used in this way: “The party is over.” Furthermore, we make no judgment about the relative value of the word over to describe the position, or about whether the learner should be taught the other meanings that are conventionally labeled with the word over. (“She’s done that paper over four times.”) The objective of a teaching communication is to convey one meaning, calling the learner’s attention to a particular sameness. We select a word that is conventionally acceptable for this purpose. Then we teach the learner about the relevant sameness, using the word that we have selected.

Concrete Examples

We have already alluded to the notion that a set of examples must be shown to induce basic concepts. It is logically impossible to present a single example of a basic concept that shows only one concept. The reason is that an example capable of showing only one concept would have to possess only one quality or property. It would have to exist without any features that are irrelevant to the concept. If we are teaching redness, the example would have to show only redness—not space, position, duration, shape, or other identifiable non-color features. Such examples do not exist.

To determine the other concepts or qualities that a particular example of red exhibits, we ask, “Could this object be used as an example of ____?” Let’s say that a concrete example of red is a rectangular piece of red felt placed on a felt board. The test of the other concepts this example exhibits discloses that the example could be used to demonstrate an indefinitely large number of other concepts. The concrete example is an example of cloth, of felt cloth, of felt cloth of a particular shape, of felt cloth in a particular place, of an object, of a solid object, of an object smaller than a breadbox, of an object smaller than a dog, of an object smaller than . . . , of the number 1, of the number 4 (four corners), of on, of above the floor, of . . . The list continues indefinitely. Furthermore, a similar indefinitely long list can be constructed for any example that is presented to show a basic concept.

Although a concrete presentation is an example of thousands and thousands of concepts, the set of concepts generated by one concrete example is never the same as the set generated by another example. The reason is that if the sets were identical, the examples would be the same in every conceivable detail, which means that they would occupy the same place at the same time. They would therefore be the same example. Given that they are different examples, there is a difference between them, which means that we can make observations about one of the examples that we
cannot make about the other. By manipulating the differences of examples, we can rule out irrelevant qualities that are inevitably present in the isolated example.

Analysis of Communicating Sameness

The learning of basic discriminations or concepts is inductive. The teacher treats concept examples one way (uses a common signal). The learner must identify the qualities that are referred to and learn that the word serves to signal the qualities.

Figure 2.1 shows five examples, each of which is labeled “glert.” The word glert, therefore, stands for some particular feature or combination of features. The features of each example are represented by the letters A, B, C and D. Example 1 is presented first, and example 5 last.

Example 3 shows that D is not necessarily a feature of glert. This communication is achieved through the following inferences: the examples of glert can be treated the same way only if they are structurally the same. Example 3 is treated the same way as examples 1 and 2. Example 3 does not possess feature D. Therefore, feature D is not a necessary feature of glert.

The communication provided by the entire set of five examples suggests that A and B are necessary for glert. Both A and B appear in all examples and they are the only features common to all examples. However, the communication provides the following possibilities:

Glert refers to A.

Glert refers to B.

Glert refers to A and B.

A communication that is effective in showing that A is the only feature relevant to glert follows a juxtaposition rule for showing sameness. The rule: To show sameness, juxtapose examples that are greatly different; treat each example in the same way. (To juxtapose examples, present one immediately after the other or position the examples next to each other.)

Figure 2.2 draws a set of five examples that is consistent with the rule. All examples are positive instances of glert. All are treated in the same way (by being referred to as “glert”). And the sequence juxtaposes maximally different examples. The first example has four features (A, B, C, D). The second example has one feature A. Since both examples are called “glert,” the concept of glert cannot be associated with what is different about the two examples, but only with what is the same—feature A. Different arrangements of examples would be as effective as the one given; however, any effective arrangement should juxtapose examples that are greatly different.

Analysis of Communicating Differences

Just as structural sameness is implied if all examples are treated in the same way, a structural difference is implied if two examples are treated in a different way. The difference assumption is: If two things are treated differently, the examples must be different with respect to some feature. A poor communication is one that presents negative examples that are greatly different from the positive examples of the concept. Figure 2.3 shows why large differences are ineffective.
These juxtaposed examples differ in A, B, C and D. The behavior of the teacher signals that there is a structural difference between the examples (calling one example “glert” and the other “not-glert”). The problem is that there are many differences between example 1 and example 2. The only difference that “causes” example 2 to be treated differently from example 1 is the absence of A. All the other features are structurally irrelevant. The communication provided by the juxtaposition of these examples, however, provides many possible options about which features cause the change in the teacher’s behavior. Stated differently, if a capable learner received the information provided by the communication above, the learner might not identify the example in Figure 2.4 as “not-glert.”

The learner may identify it as “glert” or as “not-glert.” Both possibilities exist because the presentation of the two demonstration examples is not specific about the minimum difference between “glert” and “not-glert.”

The rule for articulately communicating differences through examples is: To show difference, juxtapose examples that are only minimally different and treat them differently. Any structural difference observed in the juxtaposed examples can function as a possible basis for the different treatment of the examples. There is only one structural difference between examples 1 and 2 above in Figure 2.5. Therefore, there can be only one structural basis for the different treatment—the absence of feature A. This prescription for showing differences is contraintuitive, but logically compelling. If the only difference between the two juxtaposed examples is a small difference and if the examples are treated differently, the small difference must be solely responsible for the different behavior. Communication of the very small difference logically implies that differences that are larger than the one shown would also lead to the examples being identified as “not-glert.”

Operations to Induce Generalizations

Although the procedures for demonstrating sameness and difference will achieve the desired communication goal, a deeper analysis of operations used to induce generalization provides a clearer understanding of why these operations work. This analysis identifies three specific operations: interpolation, extrapolation, and stipulation.

Interpolation. In its most basic form, the operation of interpolation assumes changes along a single stimulus dimension, such as color, size or position. Figure 2.6 shows color gradations, from light blue to dark blue. The display does not suggest that all features of color (hue, saturation, intensity) are taken into account, merely that the examples are arranged progressively from light to dark.

The three X’s indicate examples that are communicated to the learner as being the same. If they are the same, then what is being labeled as “blue” must be what they have in common (the range of the color value being labeled “blue”). According to the operation of interpolation, if the learner receives the communication about the three examples, the learner will identify any example that is intermediate in blueness as “blue.” For example, the learner should identify examples O and P as “blue.” (No example shown above would be presented on a continuum. The continuum is used
There are other forms of interpolation. One form involves the addition or subtraction of parts. Although this form deals with a generically different type of interpolation, the basic operation is the same. If the generalization example falls within the range of interpolation described by the demonstration examples, sufficient information for generalization is implied.

If we deal with very complex examples, we might not be able to precisely express the nature of the various features that change from one positive example to another. However, if we show examples that are greatly different from each other, and if we treat these examples in the same way, we imply interpolation of most new examples. The reason is that the examples we show initially would not be placed close to each other on a continuum. Any new example would probably fall somewhere between the examples demonstrated. Therefore, interpolation is implied.

The examples that are used to demonstrate blue would not predict that the learner would generalize to a shade of blue that is quite white and unsaturated. The reason is that this shade does not clearly fall on the continuum implied by the examples that we had presented. To solve this problem, we must present a larger number of examples. Let's say that we present three variations for each shade of blue—each variation presents a different saturation and hue (see Figure 2.7).

The presentation consists of nine examples (the X's). The test of generalization involves six. The six examples are clearly interpolated within the range of variation described by the nine demonstration examples; therefore, the communication implies that all variations of O and P would be identified as blue.

Extrapolation. According to the principle of extrapolation, if a small change makes a positive example negative, larger changes will also make the example negative. The differences of the various examples in Figure 2.8 is indicated by their position on the continuum of change. The learner is shown three examples. Two are labeled “blue” (the X's) and one “not-blue” (the Y). The last two examples are quite close to each other on the continuum (to communicate difference). If the examples are only minimally different and are treated differently (one called “blue,” the other “not-blue”) the structural basis for the different label is unambiguous, because there is only one apparent difference in the examples.

Extrapolation is based on this idea: The difference between the second X and the Y is sufficient to make Y a negative example. Any difference that is greater than this difference implies that the examples will also be negative. The difference between X and O is greater than the difference between Y and O; Y is negative. Therefore, O must be negative also. Similarly, the difference between X and P is greater than the difference between X and Y. Therefore, P must be negative.

Another way to conceive of this sort of extrapolation is to visualize a concrete example, such as a patch of dark blue. Now consider how much change in the example is needed to convert the example into something that is not-blue. Changes greater than the amount create examples that are obviously not blue.

Stipulation. Stipulation involves repeatedly demonstrating examples that are highly similar and presenting only these examples. Each example is treated in the same way. The stipulated set of examples implies that any examples falling outside the range that had been demonstrated are not
to be treated in the same way.

Figure 2.9 shows that the non-naive learner is presented with eight examples that are quite similar to each other in every respect (X’s). The communication does not present any additional demonstration examples. When tested on example P or example O, the learner would probably treat it as a negative example. The outcome is problematic because the learner is not given precise information about the range of variation that is permissible for the X’s. The communication shows only that when the examples of a particular type are presented, they are treated in the same way. Examples O and P are not the same type (because their obvious structural differences sets them apart from any examples that had been demonstrated). Therefore, a reasonable inference is that they are probably not the same as the X’s, and are therefore negatives.

Stipulation depends on the number of examples that are presented. If we presented the learner with this single example and labeled it “glup,” we would not be surprised if the learner identified this test example as “glup”:. However, if we presented the learner with 20 vertical examples and labeled each as “glup,” the probability is greatly increased that the learner would identify the slanted test example as “not-glup.”

One way to understand what is happening when stipulation occurs is to think of a particular concrete example and the various features it has (see Figure 2.10).

If we repeat this example again and again, we imply that the essential sameness possessed by the positive examples includes all features, A, B, C, D. If we later present an example that is different—one that has only A and B—the learner will probably reject it because features that have been implied to be essential are missing.

Examples of Complex Concepts

When we deal with complex learning, the communications involve a combination of stipulation, interpolation, and extrapolation. Consider the situation in which we present an operation for figuring out how to add numbers. The operation involves the same counting steps when it is applied to different examples. The operation therefore stipulates some behavior for all examples encountered. The examples presented show some range of variation. Some examples involve one-digit numbers, some involve two. Some problems present the largest number first. These examples communicate sameness by demonstrating that the same addition operation holds for a range of counting numbers and arrangements. Also, if the examples suggest that a change from one digit to two digits does not affect the operation and that a change from smaller numbers to larger numbers does not affect it, the learner could reasonably be expected to “extrapolate” and conclude that the operation holds for any number.

In summary, we communicate with the learner through examples. The game is something like trying to view a vista through a very small peephole, a glimpse at a time. The learner has the capacity to make a consistent “whole” or gestalt from what we show. The glimpses we provide are examples. The idea is to provide the learner with enough information to make a consistent whole from the examples. We do not want to induce distortion or misrules by showing poorly-selected glimpses.

One and Only One Generalization
Our objective, as noted earlier, is to design communications that lead to only a single generalization or interpretation. In other words, a communication should be faultless. Only if it is faultless do we receive unambiguous information about the learner. If there is more than one sameness for the various examples that are treated in the same way, the communication has faults. The learner may respond to an inappropriate sameness. Each sameness describes a generalization. Therefore, the inappropriate samenesses imply inappropriate generalizations. Conversely, if there is only one sameness that is possessed by all positive examples, there is only one possible generalization.

A communication that is analytically faultless is faultless for any learner. Viewed differently, any naive learner needs the same information about the nature of the concept—about which changes create negative examples, and about which changes do not. Although, by chance, a learner may pick up the appropriate information from a presentation that has faults, the learner is as likely to pick up inappropriate generalizations. This situation is possible whether the learner is “very bright,” or “slow.” The variable is not the learner, but the communication.

Faultless communication does not imply that there is only one possible communication that will work for “all” learners. Since there are countless examples of a given concept, there are potentially countless variations of faultless communications. Each variation would use different examples. However, all variations would be the same in many respects. All are based on the quality or concept being taught.

Let’s say we wish to teach the naive learner the grade of a hill, angle of the hill, or slant of the hill. Our goal is to teach one of these labels, and to show the learner what it means. Let’s say that we choose to refer to the steepness of the hill.

The most efficient way to communicate with the learner is through the continuous conversion of examples. Continuous conversion occurs when we change one example into the next example without interruption of any sort. Hold up your hand in an angle about like this: . Give a behavioral indication for this example: “See this.” Now move your hand to about this angle: . Say: “It got steeper.” You have created an example through continuous conversion. You change the first display into the example (“It got steeper”). Continuous conversion of examples logically provides the most precise communication with the learner. The reasons are: Many aspects of the display appear in all examples and are therefore shown to be irrelevant. If you presented a series of continuous conversion examples with your hand, your hand would be in every example. The hand, therefore, could not account for the fact that some examples are “positive” (steeper) and some are “negative” (not-steeper). The differences in the slant of the various examples would be the only basis for difference in the labels of the examples. It is possible to show only those changes in the example that lead to a change in label. Let’s say that you start with your hand in a particular position. You then create the simplest change that permits the next example to be labeled “it became more slanted.” You must change the aspects of the display that have to do with slantedness (you must rotate your hand). No other change will achieve the objective of creating an example more slanted. It is possible to make that change and no other change when examples are presented through continuous conversion. It is possible to show the type of changes in the relevant dimensions that do not lead to a change in label. The relevant dimension is the one that is used to create a position from a negative example or vice-versa (rotation of the hand for the concept slanted). If we show the learner that certain changes in this dimension lead to changes in the label, we should also show a very small movement of the hand that is labeled, “It got steeper,” and a very large movement that is labeled, “It got steeper.” Both involve rotation, but both are obviously different from each other. The amount of change from positive example to positive example, therefore, is not relevant to “It got steeper.”

For many concepts, continuous conversion is not possible. However, the communication through
continuous conversion provides us with the guide or model for creating non-continuous-conversion sequences. The controls that are automatic in a continuous conversion sequence must be carefully constructed if we are required to present static examples to communicate the same information so well provided through continuous conversion.

Individualized instruction as it occurs in the home (when the mother instructs the child) often involves continuous conversion. The mother tells the child to do something: “Put a fork here.” The child makes mistakes, putting a spoon in the designated place. The mother converts one example to the next: “No, honey, a fork, not a spoon. Here’s a fork.” The spoon is replaced with the fork and the learner receives specific information on the correlation between the differences in label and difference in example.

A Faultless Sequence

A faultless communication consists of two parts. The first shows what controls how the example is treated. The second shows more about the context in which the concept or quality may occur. Figure 2.11 shows a faultless presentation for the concept getting steeper.

The first 11 examples show what controls getting steeper. The first five are “modeled” by the teacher, which means that the teacher tells the answers. The next six examples are tested. Following example 11 are examples that show the learner something about the range of contextual variation in which steeper occurs. The examples present objects not shown in the initial part of the communication (lines, pencils, hills) and different types of tasks (touching, naming a hill, etc.).

Different examples in the first part of the sequence have different functions. Some show differences (examples 1-3 and 5-6). Minimally different examples are juxtaposed and are treated differently. Sameness is shown by examples 3-4-5. Greatly different juxtaposed examples are treated in the same way. Examples 6 through 11 have the functions of testing the learner and of presenting examples whose values are implied by interpolation or extrapolation created with the first five examples.

The communication should be nearly faultless because it does an adequate job of demonstrating what controls the label and of not stipulating that the label is used only in connection with the presentation of hands. Examples 12 through 14 are different enough from hands to prompt the extrapolation of the concept to a wide range of examples not shown in the teaching. The presentation for getting steeper is faultless enough to permit rigorous study of the learner. If the learner does not generalize to new examples that are presented with the hands or does not extrapolate to new examples that do not involve the hands, the outcome cannot be explained with reference to the communication or the “stimulus.” An explanation must be sought by reference to the learner.

Related Sequences for Related Concepts

The presentation above is adequate to communicate the structure of the concept getting steeper. With modifications, it is adequate for communicating any closely-related concept. Any changes in the structure of the concept, however, imply changes in the communication. If we present the concept greater grade instead of getting steeper, we could use the same examples and change only the label that we use. The reason is that the only difference is the label. If we change the concept so that both the label and the structure change, additional changes are needed. For instance, if we present getting faster, the label must change and the nature of the examples must
change. We cannot demonstrate “faster” by showing “steeper.” However, since both concepts (getting steeper and getting faster) are comparatives, they have structural details that are the same. These structural details imply samenesses that should be retained in the communication.

To teach getting faster, we can start with something that is moving. We can then model the changes that occur in the example after the type of changes that occur in the sequence for getting steeper. If there is a big change in the positive direction to create an example in the getting-steeper sequence, we will introduce a big change in the positive direction for the corresponding example of getting faster. If there is a small positive change in the getting-steeper sequence, we will make the corresponding example for the getting-faster sequence by introducing a small change in the positive direction. Figure 2.12 shows the first five examples of a positive sequence for getting faster. For all examples, the object moves in a circle. The size of the circle and the direction of the object remain the same for all examples.

These examples precisely parallel the first five examples of the sequence for getting steeper. The structural aspects of the two that are the same appear in both sequences—particularly the size of the change from example to example and the direction of the change. The prediction would be that if the sequence for getting steeper is faultless and if the concept of getting faster has the structural samenesses that are reflected in the samenesses of the two sequences, the sequence for getting faster should also be faultless.

Stimulus-Locus Diagnosis of Learning Failure

An implication of the stimulus-locus analysis is that the primary diagnosis of learning failure should be a diagnosis of the instruction the learner receives. If the learner fails to generalize, the problem may lie with the learner or with the communication the learner receives. We can rule out one of these possibilities by assuming that the communication is responsible for the observed problem. The remedy is to identify faults in the communication the learner is receiving and correct them so that the communication is faultless. If the faultless instruction fails, we know that the problem is with the learner and not with the communication. If the faultless instruction succeeds, we know that the initial problem was indeed with the communication.

This diagnostic procedure is the opposite of the traditional diagnostic procedure, which assumes that the learner is at fault for any learning inadequacies. The fact that the traditional diagnostic procedures hold the learner responsible can be ascertained by referring to the percentage of case histories in which the learner's deficiency in reading, for instance, is judged to be caused by poor teaching. The percentage consistently hovers around zero, implying that the traditional diagnostic paradigm assumes that the learner has the deficiency. Not only is this position improbable, it is also illogical. Any diagnosis begins with an observation of behavior. This behavior may be influenced both by deficiencies in instruction and deficiencies in the learner. To assert that the behavior is “caused” either by learner inadequacy or by teaching inadequacies is to go far beyond the data.

The value of the initial hypothesis of the problem (that the teaching is the sole cause of the learner's problem) is that it requires us to rule out the possibility that instructional variables could account for learner failure. The hypothesis requires us to identify flaws in the instruction the learner has received and to provide faultless instruction. The prediction is that when we provide faultless instruction, the learner’s problems will be solved.

Regardless of the outcome of this test, we will receive very precise information about the actual status of the learner’s problem—the extent to which the problem is caused by learner inadequacy
and the extent to which it is caused by instructional deficiencies. If the learner responds to the faultless instruction by learning the samenesses or generalization conveyed by the faultless instruction, we conclude that the learner’s initial problem was caused primarily (or solely) by instruction. If the learner remains virtually unchanged after the introduction of the faultless communication, we conclude that the learner’s original problem was inadequacies in the learner, not inadequacies in the instruction. An intermediate outcome provides us with an intermediate conclusion: part of the learner’s problems are caused by the learner, and part by the faulty communication.

If we accept the traditional approach to learning failure, we receive no diagnostic information that translates readily into instruction. If the learner’s deficiencies are caused by learner inadequacies, how do we perform an instructional remedy that will reduce the learner inadequacies? The instruction is not suspect, so there is no reason to change it.

Illustration

Let’s say that we observe a naive learner who has been taught speech behavior by one teacher in the same setting and the learner does not practice the newly-learned behaviors with other people in other settings. The instruction has a serious fault. Specifically, it is guilty of stipulation. All examples of learning language or speech skills have a large set of common features—the teacher, the details of the setting, and nature of the tasks. A prediction based on this fault is that the learner will not perform with other people. The skills will not “transfer.”

If we attempt to diagnose the learner instead of the instruction, we will probably conclude that the learner is poor at generalizing, implying that the problem is caused by learner inadequacy. This diagnosis does not suggest how we can make the learner adequate or how we can rule out the possibility that the learner has responded in a perfectly reasonable way to the communication.

The stimulus-locus diagnosis assumes that although the learner clearly failed to “transfer,” this failure is not caused by learner inadequacies, but is consistent with the instruction received. The solution is to modify the instruction.

Summary

Basic communications are the most important units for a technology of instruction. They present concepts or qualities that cannot be fully described to the learner in words because the learner lacks knowledge of which quality is being labeled. The communication consists of examples and behavioral signals presented with the examples.

Any samenesses shared by all examples treated the same way describes a generalization.

The test of this sameness may be performed with any stable response from the learner. For the simplest form of the test, the learner is presented with a series of test examples (some of which may be different from those presented during the earlier demonstration) and the learner indicates whether each is an example of the concept. If we test the learner first by requiring a pointing response, then by requiring some other response to the same examples, we discover that the pattern maintains, although the response changes. Since all that remains is the pattern, the teacher must have introduced this pattern.

The examples that are used in a basic-communication sequence have an indefinitely large number of qualities, each of which could theoretically serve as the basis for possible generalizations. One example, therefore, cannot possibly teach. Subsequent examples must be used to rule out some possible generalizations and to confirm others. In the end, the teaching of the concept requires a
set of examples. The learning process is inductive. The learner is simply shown which examples are the same. The learner must identify the sameness that binds them.

In manipulating the examples to rule out particular interpretations, we follow juxtaposition principles.

To show sameness, we juxtapose examples that are greatly different and we treat each example in the same way.

To show difference, we juxtapose examples that are only minimally different and we treat the examples differently.

The three operations that describe our primary manipulations with the set of examples are: interpolation, extrapolation, and stipulation. Interpolation is based on a display that treats obviously different examples in the same way. If the range of variation shown by these examples does not cause the label to change, an intermediate value or change should also be treated in the same way.

Extrapolation is efficient for ruling out a range of negative examples. If the change from a given positive example to a minimally different negative causes the negative to be labeled differently, a greater change in the same direction from the positive will also result in a negative example.

Stipulation is the repeated presentation of examples that have a great many samenesses. The presentation implies that all features of these examples are necessary to the label. The result is that if the learner is presented with variations in any features, the learner will not treat the example in the same way as the original examples.

The most efficient way to show relevant changes in the examples and to label these unambiguously is through the process of continuous conversion. The process involves presenting an example and then converting it into the next example, providing the learner with a demonstration of only the difference between the examples. The difference is then labeled. The two examples are either treated in the same way (implying that the change was relevant to sameness) or in a different way (implying that the change caused a change in the label).

By combining the principles of showing sameness, showing difference, and testing on generalizations, we can create a basic communication—a set of examples accompanied with wording that tells and wording that tests. If a given presentation proves to be faultless, we are provided with a possible model for creating faultless sequences for discriminations that share many structural features with the concept taught in the original sequence. We simply change the parts of the sequence that process structural details that are different.

Finally, we may use the analysis of communication as the basis for diagnosis of learning failure. Instead of diagnosing the learner, we begin by diagnosing the instruction. We identify flaws in the instruction and correct them, with the assumption that the learner's problems were caused by flaws in the instruction. This hypothesis requires us to control the instruction or communications and then test the learner. Regardless of the outcome, we will receive very precise information about the learner.
Chapter 2 demonstrated that concepts with the same basic structure (getting steeper and getting faster) could be processed through faultless sequences that had the same basic structure. By extending the relationship of sameness in concept structure and sameness in communication, we are provided with a basis for categorizing types of knowledge. In this categorization, concepts that have the same structure are placed in the same class. Concepts within a class share structural similarities. Because these structural similarities parallel similarities in the structure of the communication used to convey the concepts to naive learners, concepts within the same class may be processed through variations of the same communication.

The two objectives of organizing different types of knowledge are: To provide an exhaustive system that permits classification of any cognitive operation, from simple discriminations to complex operations. To link the classification system with instructional procedures, so that all concepts within a particular class or category may be processed through variations of the same communication form.

This chapter describes the classification system. Subsequent chapters articulate the instructional procedures implied by the various categories of the classification system. We will first examine the stimulus-locus classification for cognitive skills (based on analysis of the cognitive operations). We will then outline the response-locus classification (based on analysis of learner's characteristics when learning new responses).

Classifications for Cognitive Knowledge

Basic Forms (sensory-feature concepts)    Non-comparatives  Comparatives  Nouns

Joining Forms (relationships between sensory-feature concepts)    Transformations

Correlated-features relationships

Complex Forms (chains of joining forms)    Cognitive problem-solving routines

Communications about events (fact systems)

The three major categories within this system are presented in order of ascending complexity. Concepts within the first category (basic forms) are the simplest concepts. The communications that are appropriate for communicating them present single-step tasks or questions with the same, single question used for all examples in the sequence. Getting steeper is a basic form concept. Each test item for this concept asks a single question: “Did it get steeper?” All positive examples are responded to with the same response, “Yes.” The goal of each of these communications is to teach a single concept.

The communications for the second category, joining forms, are more complicated. For some of these sequences, more than one question or task is presented with each example. For others, a single question is presented with each task; however, the appropriate response changes from positive example to positive example. The goal of each communication within this category is not to teach a single concept, but to teach a single relationship.

The communications for the third category, complex forms, are more complicated than the joining-form communications. For each example presented in a complex form communication, the learner must perform a series of steps. These communications are not designed to teach a single concept or a single relationship. Rather, each is designed to teach a set of relationships that are appropriate either for solving problems of particular types or for learning about the set of features that distinguishes one event from another. In either case, the communication presents a series of familiar concepts or relationships that are combined in a unique manner.
The classification indicates the most precise communication that is logically possible for each type of concept. The most precise communication possible for basic forms is basic forms. The most precise communication possible for joining forms is joining forms; however, it is possible to treat any joining form concept as a basic-form concept. Similarly, it is possible to treat any complex form as a joining form or as a basic form. The matrix on page 20 shows the relationship between the type of concept and the classification options available for that type. The cells in which the X is circled show how each type of cognitive operation is classified in the system. According to the matrix, any concept may be treated as a basic concept. If we were to treat the concept of carrying out a long-division operation as a basic form, we would present it through a communication that follows the same pattern used for all basic forms. We would present examples of working long division problems. For the examples that test the learner, we would ask the learner, “Is that the right way?” For some examples, the answer would be “yes” and for others, “no.” This is not the most precise communication that is possible for the concept of the long division operation (or of a particular algorithm for working long division problems). A more precise way would be to show the learner the steps involved in working the problem. The concept of a long-division operation is a complex form—one that involves many steps, many concepts, and discriminations linked together.

Basic Forms

Basic-form concepts are the simplest form because they cannot be reduced to simpler forms, and they cannot be clarified through verbal explanations. Basic-form concepts refer to specific meanings of words like red, under, back, truck, door, sit, horizontal, and girl. To communicate any basic form, we must present examples, some of which show what the concept is (positive examples), and some of which show what the concept is not (negative examples). There are several ways to test a concept to determine whether it is a basic form concept. The simplest way is to start with any sentence that conveys a relatively specific meaning, such as:

“Look at the red block under the table.”

Earlier we noted that we are not dealing with words when we analyze concepts, merely meanings. The use of a sentence as a starting point does not contradict the earlier statement. In fact, the use of the sentence illustrates the difference between analyzing words and analyzing concepts. In the sentence, each word has a single, clear meaning. However, each word in the sentence has many possible meanings when the word is considered apart from the meaning conveyed in the sentence. Look could be a noun or a verb. It could refer to the appearance of something (“The new look”). Similarly, the word red apart from the sentence could refer to color or anger (“I saw red”). The sentence conveys the various meanings that we are to deal with. It also presents conventional labels for each meaning. The meanings that we will consider are those conveyed by the sentence. The words that we will use to signal each meaning are those contained in the sentence.

The smallest conceptual units signaled in the sentence are basic-form concepts. The concept look is a basic-form concept. So are the concepts red, block, under, and table. We cannot reduce these concepts or break them into components. If the learner does not know the concept under, we gain nothing by telling the learner, “It's under because it is below,” or “When it's beneath, we say it's under.” We would still need to teach the meaning of the new word that we introduce in the explanation—beneath or below. Since these words have the same communication function in the sentence as under, we would create an unnecessary step by introducing the synonym. The most direct and precise communication would be one that teaches the meaning of under that is used in the sentence. To convey this meaning, we would present different examples that show an object in different positions with respect to another object. We would label some examples “under” and
Variations of the same procedure are used for all basic-form concepts. The basic form concept under is a non-comparative, which means that a given static example that shows something under is always an example of under. The concepts of getting steeper and getting faster are different. They are comparatives. An example of a particular grade is not always an example of steeper. It is steeper only when compared to an example that is less steep.

The final type of basic-form concept is a noun concept. Nouns are the meanings referred to by words like shoe, building, magazine, chalk, and other noun words. Nouns are basic forms that are structurally different from both comparatives and non-comparatives with respect to the number of dimensions that can be operated on to change a positive example of the concept into a negative. For non-comparatives (like under), only a single change in a positive example will make it a negative example. (For under, this change involves the spatial relationship between the two objects in the example.) Similarly, for comparatives (like getting steeper), changes in only one dimension will convert positive examples into negatives (for the concept of getting steeper, the change is the slope of the object). Both comparatives and non-comparatives are single-dimension concepts. Nouns are multiple-dimension concepts, which means that it is possible to change a positive example of a noun into a negative example by manipulating many dimensions of the object. (We can change a jacket into a non-jacket by changing the material, length, shape, by removing parts, and by adding parts.) The structural uniqueness of nouns suggests some unique features of communications that convey nouns faultlessly. However, nouns, like comparatives and non-comparatives, are simple, irreducible concepts that are based on the sensory features of objects or examples.

Joining Forms

Non-comparatives, comparatives, and nouns are signaled by a single label or by a group of words that functions as a single label. Joining forms, in contrast, involve relationships between basic-form concepts. Therefore, joining forms involve two independent labels that are related in some way. The joining forms are the simplest ways that logically unrelated concepts such as under and table may be combined. We can illustrate the relationship between basic forms and joining forms by referring to the concept under. After the learner has mastered the discrimination of under—not-under (basic form discrimination), we may combine under with other concepts that are logically unrelated to under.

One way to create a link between under and another concept is through a transformation. A transformation is systematic ordering of examples and a parallel ordering of symbols used to describe the examples. If the learner knows the positional meaning of under and understands the meaning of basic noun labels, such as table, shoe, etc., and we could combine these concepts with under using a transformation sequence. We would present different examples of an object in different positions. The learner, however, would not simply indicate whether the object is “under,” or “not-under.” Instead, the learner would produce a unique verbal response for each test example by telling where the object is. The learner’s responses to different examples would be: “Under the table . . . under the shoe . . . under the bed . . . under the shelf . . . under the book . . .” If the sequence used to communicate the joining that occurs when under is linked with these objects is faultless, the learner should be able to generalize to a new example, one that had not been presented during instruction. For instance, if the learner is able to identify “pencil,” the learner should be able to produce the new, appropriate response, “Under the pencil,” when presented with an example that shows the target object under the pencil. Note that this response is one the learner had never produced before. The fact that the learner produces it implies that the learner has learned the transformation procedure for how to express the basic way that under is
joined with other basic-form concepts.

Another way that basic-form concepts are joined together is the correlated-feature joining. This joining is not based on a system of ordered responses that change according to a transformation rule, but rather on empirical associations. If two things happen together, they are correlated. However, the two things involved in this correlation are logically unrelated, which means that the learner could exhibit complete basic-form understanding of both things involved in the correlation and yet not know the correlation. The following sentence expresses a correlated-feature joining involving under: “If it is under, it is below.” The learner could be proficient at identifying all possible examples that require the learner to label the example as “under” or “not-under” without understanding that each example has another label—below. The relationship between the words is based on an empirical fact—by convention, examples of under have another label, below.

To teach the relationship between under and below, we would use the same sequence of examples used to communicate under. The reason is that under and below vary together. If something is labeled under, it is always labeled below. If the object is non-under, it is not-below. Therefore, the same set of examples and sequence of examples used to communicate under would effectively show what controls the label of below. To assure that the relationship between under and below is made explicit, however, we would not ask the same question that we use in the sequence for under (“Is it under?”). Instead, we would present a pair of different questions to show the relationship. The first requires the use of the new label (below). The second requires the learner to express the correlation between under and below.

Figure 3.1 shows the first three examples from a possible faultless sequence.

Since all correlated-feature relationships are the same (based on an empirical relationship between the basic-form concept that is known to the learner and the concept that is correlated with it), we can use the same communication procedures to faultlessly convey any correlated-feature concept. Below is the first part of a correlated feature concept that involves steeper grade. Note that the sequence of examples is the same as that used to communicate steeper grade. However, the questions are changed to assure that the learner learns the relationship between the grade and the speed of the object.

Whether the joining form involves a transformation or correlated features, the concept is not a basic form concept. It is a relationship between basic-form concepts, and the relationship cannot be reduced to simpler concepts. The relationship is irreducible because knowledge of any basic form concept does not imply its relationship to other concepts. Knowledge of under does not imply the system of ordered responses used to refer to “under the table . . . under the chair . . .” etc. Knowledge of under does not imply knowledge of the word below. Knowledge of steeper grade does not imply knowledge of moving faster. To connect these logically unrelated concepts, we use communication forms that show how the basic concept that is familiar to the learner is related either to the system of ordered responses or to some empirically associated concept.

Complex Forms

There are two types of complex forms—cognitive problem-solving routines and communications about events (fact systems). Both cognitive problem-solving routines and communications about events require the learner to attend to various details present in the example. The various details require multiple responses from the learner—each dealing with different aspects of the problem
or event. Therefore, complex forms are distinguished from simpler forms by the multiple responses involved in processing each example.

If complex forms are to be unambiguously introduced to the learner, they should process concepts through a series of verbal instructions or directions. The directions tell the learner what to do, what to attend to, or how to label some features of the examples. Since any series of verbal instructions is composed entirely of basic-form concepts or joining-form concepts, the complex forms are of a higher order than either joining forms or basic forms.

Cognitive Problem-Solving Routines

The juxtaposition pattern for the complex forms is different from that of basic or joining forms. A sequence for a basic form presents juxtaposed examples that involve the same response dimension. The sequence strongly prompts the learner to attend to this dimension, because attention is never drawn from the single response dimension. With slight exceptions, the joining forms work in the same way. The juxtaposed examples deal with the same relationship and there is very little interruption between presentations of examples involving the response dimension being taught. (An exception is the correlated-feature sequence, which presents two questions with each example. However, both questions deal with different facts of the same relationship: “Would it move faster? . . “How do you know?” . . .)

With complex forms, the same response dimension is not referred to in juxtaposed tasks or questions. Figure 3.3 shows a cognitive problem-solving routine for working problems of the form: $5–3=\square$.

Notice that the entire routine deals with one subtraction problem (one example). Obviously, variations of the routine could be used for any problem within the same class as $5–3=\square$; however, each example would be processed through the same nine steps. And no two steps deal with the same relationship. In step 2, the learner responds that the 5 tells us to “start with five.” If the number were different, the response would be different. Therefore, the first step would have been pretaught as a transformation, with the teacher presenting different beginning numbers and asking about each, “What does this tell us?” (The responses are ordered according to ordered changes in the examples; therefore, a transformation is involved.)

This transformation is dealt with in only one step of the routine, however. Step 3 tells the learner to start with 5 and the learner makes five lines. A different transformation is involved in this step (one that would also be pretaught). Step 4 involves another transformation, in which the learner’s responses vary as the symbols in the problem vary. Note that each step deals with a new feature or step in the solution to the problem. Note also that each step is composed entirely of basic concepts or joining-form concepts.

Cognitive problem-solving routines are appropriate for any task that may be treated as a series of steps that lead to a solution. The judgment of whether a routine is possible depends on whether the learner is logically required to process a series of concepts, details, or discriminations to arrive at the appropriate solution. An assumption is that if the logical analysis of the operation under consideration discloses that the learner must attend to a variety of discriminations, a cognitive routine is more appropriate than any other form for communicating the structure.

For example, simple word decoding for the learner who is assumed to be naive, logically implies attention to the different letters in the word and to their order. If the learner does not attend to the m in mat, the learner logically may confuse mat with hat, cat or at. If the learner does not attend to
the a, the learner may confuse the word with met. If the learner does not attend to the t, the learner may confuse mat with mad or map. This analysis suggests that we should design a routine that deals with all the various discriminations or concepts. This routine should permit the learner to produce strong behavioral signals that leave little doubt about whether the learner is appropriately processing the various discriminations.

Figure 3.4 shows a possible routine for teaching initial word-reading.

The routine assures that the sounds are produced, processed in order, and then transformed (through “say it fast”) into the word spoken at a normal speaking rate.

We observed earlier that any complex cognitive operation may be treated either as a joining form or a basic-form concept, we would simply present examples of words and give the learner instructions to say the words that we show (“look and say”). The cognitive routine is logically superior to procedures that leave the steps of the operation covert because the routine reduces the possibilities for misgeneralization. When many steps are involved in a solution, and the steps are not explicit, the learner may learn spurious strategies that work in the initial-teaching situation but that will not work later. If the initial set of words to be read contains only one three-letter word that begins with m (mat), the learner who is taught to decode mat as if it were a basic-form concept may process the example by attending to the length of the word and the beginning letter. Although this strategy will permit the learner to discriminate between mat and the other words introduced early in the sequence, the learner will encounter serious problems when mad and man are introduced, because the learner’s strategy will lead to these words being identified as “mat.”

The highly overt procedure provided by the cognitive routine is superior to the procedure that leaves the steps covert because of the nature of all cognitive operations. These operations are quite different from physical operations. Yet many tacitly stated analogies about cognitive operations proposed by some cognitive psychologists are based on assumed parallels between physical operations and cognitive ones. The two primary differences between physical and cognitive operations are: The physical environment provides continuous and usually unambiguous feedback to the learner who is trying to learn physical operations, but does not respond to the learning attempts for cognitive operations. There is no necessary overt behavior associated with any cognitive operation.

The physical environment provides feedback to the learner for all applications of physical operations. Physical operations include fitting jigsaw puzzles together, throwing a ball, “nesting” cups together, swimming, buttoning a coat. When the learner performs any physical operation, the physical environment provides feedback. This feedback takes the form of contingencies that occur if the operation is not being performed correctly. The physical environment, when viewed as an active agent, either prevents the learner from continuing or provides some unpleasant consequences for the inappropriate action. If the learner is not performing the operation of buttoning a coat properly, the physical environment “prevents” the coat from being buttoned. If the learner is not nesting a series of bowls correctly, the physical environment “prevents” the nesting from occurring. If the learner does not carry out the operation of hopping correctly, the physical environment “interferes” when the operation is not being performed correctly. The “responses” from the physical environment (the negative consequences or the prevention of the operation from continuing) have a precise communication value. They indicate that some behavior must change if the task is to be completed.

For any physical operation, we can state the behaviors that account for the completion of the operation. Also, we can completely account for any outcome by referring to the overt behaviors
produced by the learner. The learner cannot open the door without producing certain overt behaviors. Furthermore, if the door has been opened by the learner, we can account for every aspect of the outcome by referring to the different overt, observable things the learner did.

For any cognitive operation, there are no necessary overt behaviors to account for the outcome that is achieved. The practiced learner does not have to “write out” formulas to solve complex problems. The learner may solve them covertly. Cognitive operations do not exist in the sense that physical operations exist. We cannot account for the “silent reading” of a practiced learner by referring only to the overt behaviors that the learner produces. Clearly, if we are to observe the behaviors that lead to the outcome of a cognitive operation, we must design the steps so they are overt and so the outcome is accounted for by these overt steps.

The physical environment does not provide feedback when the learner is engaged in cognitive operations. If the learner misreads a word, the physical environment does nothing. It does not prevent the learner from saying the wrong word. It does not produce an unpleasant consequence. The learner could look at the word form and call it “Yesterday” without receiving any response from the physical environment.

The basic properties of cognitive operations—from long division to inferential reading—suggest both that the naive learner cannot consistently benefit from unguided practice or from unguided discovery of cognitive operations. Unless the learner is provided with some logical basis for figuring out possible inconsistencies (which is usually not available to the naive learner), practicing the skill without human feedback is likely to promote mistakes.

To build adequate communications, we design operations or routines that do what the physical operations do. The test of a routine’s adequacy is this: Can any observed outcome be totally explained in terms of the overt behaviors the learner produces? If the answer is “Yes,” the cognitive routine is designed so that adequate feedback is possible. To design the routine in this way, however, we must convert thinking into doing.

Although cognitive routines are composed entirely of basic-form and joining-form concepts, the routine is not a good vehicle for teaching these concepts. The reason has to do with the pattern of juxtapositions that occurs in a routine. Of ten only one step of the routine presents a particular discrimination. If the routine has five steps, a great deal of interference occurs before the learner receives a second example of the concept in a particular step. The learner does not receive massed practice on the critical concept (because the routine does not present juxtaposed examples that deal with this concept). Therefore, the learner’s memory requirements are increased enormously and the total amount of time needed to teach the concept is increased. Components, concepts, and skills should be pretaught before bringing them together in the routine.

A final point about cognitive problem-solving routines: they should be designed so they apply to the widest possible range of examples. Cognitive routines are inventions. Two opposing considerations are involved in the inventing process. The first is the need to make the learner’s processing steps overt. The opposing consideration is the generalizability of the routine. If each routine applies to only a very small class of problems, many different routines would be required to teach the learner how to process the entire range of problems encountered. This situation is ineffective because: (1) each routine involves preteaching (and with many routines, a great deal of preteaching is involved); and (2) if the learner must select from a variety of routines, additional discrimination training is required.

Figure 3.5 shows an example of a generalizable routine. The teacher wording is the same wording presented in the routine for processing 5–3=□. The example, however, is a negative-number problem.
The routine exhibits the basic properties of a well-designed routine. Details that appear in one problem are treated in the same way when they appear in another problem (such as making lines for each positive counter and slashes for each negative counter). The approach is maximally overtized, which means that the routine requires the learner to “show” exactly which steps the learner takes in solving the problem. Also, the learner must respond to the various details that are logically necessary to the solution. Because the learner responds overtly to every detail that is logically necessary to solve the problem, the operation has the same feedback potential as a physical operation. The outcome is totally explained in terms of the overt behaviors. We know what the learner is “thinking” and we can respond to the overt steps that are functionally necessary for performing a physical operation. This feedback must be provided by humans or machines.

Fading. Successful teaching of cognitive problem-solving routines involves “fading out” the overt steps and “covertizing” the operation so that the learner performs independently. This feature further distinguishes cognitive routines from physical operations. Fading of steps is never necessary for physical operations because such steps are always overt.

The judgments about how quickly the routine should be covertized is made by considering two competing facts: (1) the learner’s proficiency, and (2) the problem of stipulation. We should not covertize the routine until the learner is reasonably proficient with overtized routines. If our communication is to be consistent with a single interpretation, we must make sure that the learner is performing the appropriate steps. We will have this assurance only if we know that the learner performs appropriately when the steps of a routine are overt. However, the longer we work on the problem overtly, a step at a time, the more reliant we make the learner on the teacher direction. The covertizing process must proceed as quickly as it reasonably can (to reduce the stipulation problem). However, the process must not begin until the learner is proficient with the overt routine.

Communications About Events

These complex communications are like cognitive problem-solving routines in several ways. The communications are composed of steps that guide the learner. Also, juxtaposed steps deal with different response dimensions or features of the example. The primary difference between cognitive problem-solving routines and communications about events is that communications about events deal with learning about a new “whole” by learning about unique relationships of the different parts that make up this whole. The whole may be an object, such as a particular refrigerator. However, the goal is not to use that refrigerator as an example of some concept that is common to many other refrigerators. Instead, the goal is to attend to the features that make the particular refrigerator unique. To appreciate the uniqueness, the learner must attend to the sum of details that distinguish it from other refrigerators. Each distinguishing feature is expressed as a fact. “It has a scratch on this side . . . it is yellow . . . it has two handles . . .” etc.

There are many applications of communications about events. The primary one is the “expansion” of basic and joining form concepts that have been taught. Once a concept such as yellow has been taught through a basic-form sequence, the initial teaching has been accomplished. However, the use of the concept has not been established. To demonstrate the use, the concept now becomes a step in various communications about events. Let’s say that the learner has recently been taught numerals, their relationship to counting, colors and the comparative concept of bigger. For an expansion activity, the teacher writes 2, 7, and 5 on the chalkboard. The numerals 2 and 7 are white; 5 is yellow. 5 is also written bigger than the other two numerals.
Teacher points to 5. “What numeral is this? . . . What number does it tell you to count to? . . . Let’s hear you count to five . . . What color is this numeral? . . . Yes, it’s yellow. Tell me if it’s bigger than the other numbers or not bigger . . . Yes, it’s bigger.”

Unlike the steps in a cognitive routine, the steps that the teacher presents for communication about an event do not occur in a particular order, because the objective is not to convey a procedure for solving a problem (which requires a particular ordering of steps), but to deal with the features that make the 5 unique. These features may be presented in any order. In the case of the expansion activity above, the communication also plays an important role in demonstrating that the various concepts that have been taught are useful components in formulating a precise understanding of what makes the five unique. Knowledge of each component concept adds to the learner’s ability to express details of the 5’s uniqueness.

One of the more sophisticated types of communications about events involves a symbolic event that is created to teach a system of facts. Figure 3.6 shows a display that shows how factories work. The display functions as the event. The features that distinguish this display or event from others have to do with the unique spatial arrangement of details and the specific words that appear on the display. The display functions like a super outline that shows higher-order and lower-order relationships (the relationship between raw material is changed into product and the more specific instances that derive from this rule: “Cotton is changed into cloth,” etc.)

If the learner memorizes the words that appear in different parts of the display, the learner will be provided with an outline of how factories operate. Therefore, the goal of the communication is to teach the learner to memorize the wording in the various cells.

To achieve this goal, the communication first rehearses the learner on the wording in the various cells, then tests the learner with a display that is the same as the original, except that the cells are empty. The learner has to indicate the words that go in each cell.

Table 3.1 shows the communication for the teaching of the display followed by testing with the empty-cell display (Figure 3.7).

Although the classification system of cognitive skills is exhaustive and is capable of generating specific information about how to communicate any concept within a given category, the specificity of the teaching information is less for the complex forms than it is for either the basic forms or the joining forms. There are two reasons for this reduced specificity. The procedure or event may be approached in different ways (each way leading to a different arrangement of steps or facts). Different wording is possible for each step or fact and for each response the learner is to produce.

Even with the less specific guidelines for complex forms, the classification system is capable of providing important information about the structure of any concept, and therefore carries important implications about how to teach the concept.

Response-Locus Classification
The primary analysis for all cognitive operations is the stimulus-locus analysis. The development of sequences and routines does not place heavy emphasis on teaching the learner to produce new responses. The primary domain for new responses is the physical world. However, once a routine is designed, it functions a great deal like a physical operation. The learner is presented with specific stimuli that call for specific, overt responses. The learner may not be able to produce the responses acceptably. For instance, the learner may be completely incapable of saying the word “four” so that it is impossible to distinguish the response from the learner’s response for “five.” At this point, we enter the domain of response-locus analysis. We must modify the learner so that the learner is capable of producing the new response. Similar problems occur if the learner is not able to make lines for numerals, or even if the learner tends to forget the label for the numeral 5.

The response-locus analysis is also appropriate for teaching any simple physical response or chain of responses used for a complex physical operation. The learner may not be able to turn a door knob. Although the physical environment will assist in the teaching of this operation (by providing the learner with feedback on every trial), we can simplify the operation, streamline it, and provide the learner with prompts about how to approach the task.

Classifications for Response-Locus Communications

Simple Responses       Response-context shaping       Response-form shaping

Complex physical problem-solving operations

Simple Responses

Context and form. There are two primary types of response-locus instruction.

The first is context instruction. This type of communication is appropriate if the learner can produce the desired response in some contexts, but not in the context of the operation being taught. For instance, the learner can assume a “tuck” position while lying on the gym mat, but not in the response context of doing a back somersault from the diving board. The context of the response must therefore be shaped or changed so the learner learns to perform in the desired context. A different type of context-shaping problem is one in which the learner can say a word, such as stegosaurus, within the context of the task, “Say stegosaurus,” but not within the context of the situation in which the learner is asked, “What’s the name of this dinosaur?” For whatever reason, the learner is unable to remember the name.

The second type of response-locus instruction has to do with form. The learner cannot produce the response in any context. The learner is told to “Say stegosaurus,” and the learner responds with something like, “Dedgustus.” When we try other contexts, we can find no behavioral context in which the learner produces the desired response.

Shaping. The analysis of the learner discloses that practice is the primary variable for learning new contexts for responses or learning responses of a new form. The technique used to provide effective practice is shaping. There are two generically different ways a task may be made easier for the learner. The context of the task can be made relatively easier and then progressively modified to shape behavior in the new context. (The context for the task is easier if the task immediately follows a successful trial on the same task.) Also, the criterion for an acceptable response can also be made progressively more demanding. Instead of requiring the learner to produce a response of a certain configuration, we initially permit the learner to produce an approximation—any response that falls within a broader range of variation.

In summary, if the learner can produce the response called for by the task but not within the
specified task context, the shaping focuses on context changes. If the learner can produce only an approximation, the shaping focuses on the response form.

Response-locus communications are unlike stimulus-locus communications in that they do not involve a particular number of trials. The reason for this difference becomes apparent if we consider what these two analyses deal with. The stimulus-locus analysis deals with concepts and determines the type of information that is needed to communicate how the concept works—which changes affect it and which do not. The response-locus analysis is an analysis of the learner and how the learner learns. Without possessing a great deal of information about the particular learner for whom the analysis is being used, we don't know how many trials are required to bring the learner to an acceptable criterion. Instead of introducing a specific sequence, therefore, the response-locus communication involves general rules about how to change the example or tasks when the learner performs unacceptably on initial tasks.

Context shaping. The context-shaping procedure sequences contexts of varying difficulty. The easiest context is one in which an example of the task is juxtaposed to another example of that task. The most difficult context is one in which the task is temporarily removed from another example of that task. For the sake of simplicity, context-shaping may be conceived of as involving three levels of context difficulty:

The circled A in each context is the target task. Level 1 shows the task immediately preceded by a successful presentation of the same task. Level 2 shows the task preceded by the task and by some interference. B is a familiar task that is not similar to A. Level 3 shows more interference in the form of familiar tasks B, C, D, and possibly other familiar tasks not highly similar to A. The memory requirements for A on level 3 are far more difficult than those required for levels 1 and 2.

The teacher stays on a particular level until the learner is able to perform correctly on perhaps four consecutive trials. The teacher then moves to the next level. The goal is consistent performance on level 3. Throughout the training the learner will most probably receive reinforcement on at least 70 percent of the trials. Corrections, whether they occur within the current task training program or later after the skill is supposed to have been learned, involve returning to step 1 and quickly going through the various levels before repeating the task in the context in which the mistake occurred.

Form shaping. The procedures for shifting the response criterion in form shaping involve transitions similar to those indicated for context shaping. By observing the learner on a number of trials, we can determine the learner's baseline of performance. We establish a criterion that permits the learner to receive reinforcement on at least 70 percent of the trials if the learner performs no better than on baseline. When the learner's performance improves to perhaps 85 percent, the criterion is changed. The cycle is then repeated. An effective variation is to have standards for single reinforcement and for double reinforcement. The requirement for “doubles” is higher than for “singles.” The higher requirement for double reinforcement gives the learner more immediate information about the direction in which the shaping will proceed. (The difference between responses that receive singles and those that receive doubles suggests the desired direction in which the responses are to be modified.)

Complex Physical Operations

Complex physical operations, such as swimming, hitting a baseball, throwing a baseball, soldering, and dialing a number on the telephone, have some of the same features as complex routines designed to teach cognitive problem-solving behavior. Both the physical operation and the routine
involve discrete steps. Both involve creating a desired outcome by performing in a certain way. Both are composed of components that can be removed from the context of the complex behavior.

The samenesses suggest that we can use some of the same techniques designed for communicating cognitive operations when we teach physical operations; however, the approach must be modified to accommodate shaping, our primary technique for inducing the desired behavior.

Features of complex operations. All complex physical operations have component behaviors. A component behavior is one that retains the same form it has in the complex operation when it occurs in other contexts. (In other words, the same component can be identified in other tasks.)

There are two types of components—essential behaviors and enablers (or non-essential components). Essential behaviors are those that account for the outcome of the task. Enablers are behaviors that must be performed if the essential behaviors are to be performed. The essential behavior for the operation of brushing teeth is moving the brush while it is in contact with the teeth. One enabling behavior is holding the toothbrush. (If the learner does not hold the toothbrush, the direct behavior of bringing it into contact with the teeth cannot be achieved.) Note that the essential behavior occurs at the same time as the enabler. This situation is common to physical operations. The learning of physical operations, therefore, implies teaching not only the component behaviors, but also the coordination of these. Conversely, the operation would be analytically easier if it required less coordination because it would require less learning.

There are three basic strategies for beginning the instruction in a way that requires less coordination. They are: The essential-response-feature approach. The non-essential-response-feature approach. The removed-component approach.

The essential-response-feature approach begins with an operation that has been simplified by eliminating some of the enabler-response components. The learner produces the essential-response components and thereby produces the behaviors responsible for achieving the outcome of the operation. (In the toothbrushing example, the learner would do the brushing; however, the toothbrush is rigidly attached to a glove, which means that the learner does not have to grasp it. The enabling component—grasping—is eliminated so that the learner performs on a simplified version of the operations. Note that the learner does the actual brushing.)

For the first step in the non-essential-response-feature approach, the learner produces the enabling or non-essential features of the operation, but is not responsible for the essential response feature. (The learner would put the toothpaste on the toothbrush, and possibly hold the toothbrush; however, the act of brushing would be performed by somebody else.) The learner would perform only the components that accompany the essential behavior.

The third approach, the removed-component approach, begins with a particular component removed from the context of the operation in which it is to occur. The instruction may begin by requiring the learner to hold an object like a pencil horizontally and then move it up and down while maintaining the horizontal orientation.

In practicing this behavior with the wrist turned in different positions, the learner practices a component of the brushing operation. The context is simplified because it does not require maintaining contact with teeth or turning the brush so the bristles are oriented properly, etc.

The three different strategies dictate different first steps of instruction. Shaping is used to achieve the desired performance. After the first step, the learner is given increasing responsibility for the
total response until the learner is performing the operation with no prompts.

Each approach has the basic problem of distortion. Distortion is the counterpart of stipulation. It comes about because the learner is permitted to perform in a way that will not transfer to new examples or applications of the operation. The first step of the essential-response-feature program provides the learner with a very easy example. If the learner works too long on this presentation, the learner may learn to perform the response successfully, but not exactly the way it should be performed when the non-essential components are included in the operation. Although it is possible for the learner to perform on this example in a manner that is perfectly continuous with all examples of the operation (including the very difficult ones), the learner will probably perform in a way that is not perfectly continuous. The more response latitude the easy example permits, the greater the probability that serious distortion will be evident when new more difficult applications are presented.

Consider the problem of teaching the learner to button. If we begin with a very large button, we are providing the learner with a great deal of response latitude. The probability is therefore great that the learner will learn behaviors that achieve the goal of the operation, but that will have to be modified when more difficult examples are introduced. (The learner may grab the flat sides of the button between the thumb and index finger, a behavior that cannot readily be performed with smaller buttons.) The same sort of distortion is implied when the learner performs the non-essential response features of the operation. Distortion is observed when the components are integrated or when more difficult examples are introduced. Some distortion is inevitable because the simplified operation is just that—simplified. Therefore, component responses that are produced in this context are not under the constraints they will be under when they are integrated with other component responses.

To reduce the amount of distortion resulting from the initial practice, we may alternate from “easy” to “hard” examples. For instance, part of the time the learner works on a removed component; part of the time on the entire operation with no prompting. When the learner works on the entire operation, heavy use of reinforcement is used for shaping specific features of the operation. However, the primary value of this work would be to provide the learner with some sort of “advance-organizer” information about the direction the learning is to take and about the relationship between the removed component and the entire operation. A variation of this strategy can be used with either the essential-response-feature approach or the non-essential-response-feature approach. For instance, the learner might use something like a walker when learning to walk (non-essential-feature approach); however, instead of permitting the walker to support 100 percent of the learner’s weight, we would use a spring-loaded walker so that the amount of support it provided varied. During one practice session, the learner might do some walking when 90 percent of the body weight is supported by the walker, some when 60 percent of the weight is supported, and some when 45 percent is supported. The percentages would change as the learner becomes more proficient at each of the initial percentages.

Effective strategies for teaching physical operations provide a great deal of practice. Children do not become proficient at cursive writing, at typing, or at dribbling a basketball without a great deal of practice. Within the framework of providing practice, however, the approach must be an effective communication. The complex operation should not be presented as something that is atomized into a number of pieces that can be put together through a backward chain. The best programs are the simplest, with the learner performing actual instances of the operation as quickly as possible.

Communicating physical operations to the learner is different from communicating simple discriminations only in the sense that if the learner does not respond quickly or well to the initial instruction, the learner needs practice. However, the basic stimulus-locus principles of
communication still hold. If the learner works too long on a particular set of examples, serious stipulation or distortion will probably occur. If the examples that are practiced show a range of difference and show that the same basic response can be used for all applications, the communication implies a generalization. (It shows sameness of response across a range of examples.) To show differences in responses, we would use basically the same technique that we would use to show differences in examples of a concept. When dealing with physical operations, however, we must overlay the stimulus-locus procedures with the facts about practice. Even though we know that we are working on a particular example or application too long, we may be faced with a double-bind problem. We cannot go on to more difficult examples until the learner performs. However, the learner will not perform without distortion unless we proceed to other examples. The solution is a compromise. We must make the tasks easy enough to assure that the learner will succeed. At the same time, we must try to minimize the potential misgeneralization that occurs if the learner works too long on the easy examples. We reduce misgeneralization by interspersing some difficult examples early in the program. In the end, the communication that we provide will violate some principles, either in creating the initial examples or in providing the amount of practice the learner needs. The principles are violated only when necessary.

Summary

The classifications for cognitive knowledge forms and for response forms are as follows:

Cognitive Knowledge Forms (stimulus-locus analysis)

Basic Forms

Non-comparatives (single-dimension concepts)
Comparatives (single-dimension concepts)
Nouns (multiple-dimension concepts)
Joining Forms
Transformations
Correlated feature relationships

Complex Forms

Cognitive problem-solving routines
Communications about events (fact systems)

Physical Operation Forms (response-locus analysis)

Simple Responses
Context shaping
Form shaping

Complex Physical Problem-Solving Operations
The basic forms are the simplest concepts. By considering the various labels that occur in a sentence, we are provided with a single meaning of each label. The Basic-form communications consist of a series of examples that focus on the specific meaning that has been determined for a label. The sequence shows which features of the examples lead to changes in the label and which features do not affect the label. The sequence begins with a series of examples that are paired with statements about the label, followed by a series of examples that test the learner. Juxtaposed examples in the sequence deal with the same concept.

Joining forms do not deal with single labels. They involve the relationship between two logically unrelated basic-form concepts. The two types of simple relationships are a transformation and a correlated-feature relationship. The transformation sequence shows the learner how changes in the examples lead to ordered changes in the responses, thereby inducing a generalization that permits the learner to produce new responses to examples that have not been presented earlier. The goal of the transformation communication is to teach the relationship between the features of the examples and systematic changes in the responses. The correlated feature sequence shows empirical relationships between two things that occur together. This relationship is based on empirical fact. If it is an empirical fact that a steeper grade is correlated with faster movement of an object down the grade, a correlated-feature sequence is implied. The communication for this relationship presents the same set of examples that would be used to teach steeper grade; however, the questions are different. The first asks about “faster.” (Did the object go faster?) The second links this conclusion with the evidence presented in the example. (How do you know?)

Complex forms are characterized by the logical requirements that the learner must attend to various dimensions or features of the example to understand the concept. The communication makes the learner’s attention to these dimensions or features explicit or covert. Because the communication deals with sets of relationships rather than a single relationship (which is what the joining forms communicate), the juxtaposed questions or tasks in the complex communication do not deal with the same details or features and do not call for responses that deal with only one dimension. Therefore, these communications are not well designed to teach basic-form concepts or joining-form concepts.

The two types of complex communications are cognitive problem-solving routines and communications about events. The problem-solving routine is a cognitive counterpart of a physical operation—a creation that provides the learner with the various steps that are logically required to solve any problems of a specific type. (In other words, the same series of steps would be presented for all problems of a given type.) The routine is designed so that the learner produces overt responses for the various discriminations or details that logically must be processed if the learner is to solve the problem. The overt character of the processing assures that the teacher is able to observe the relevant details of the learner's processing and therefore is able to provide feedback (in the same way that the physical environment provides feedback on the learner's attempts to perform physical operations). The cognitive problem-solving routine is an initial-teaching communication. After the learner has mastered the overt routine, the steps are “faded” or made covert so that the learner processes these steps independently.

Communications about events consist of a series of tasks and instructions that are designed to articulate the unique character of events by pointing out the unique character of the individual features and the relationships that exist among the features. Unlike cognitive routines, the communications about events do not involve a particular order for processing the information. Communications about events, therefore, require the learner to learn the parts and relationships when these are referred to in any order. The visual-spatial display represents a sophisticated event that functions as a super outline showing the key relationships between various facets of a system of facts.
The response-locus-analysis is an analysis of the learner and therefore involves a classification system quite different from that for cognitive operations. Since the learner learns new responses and overcomes response deficiencies slowly, it is not possible for these communications to specify a set number and type of example to teach a particular skill. Instead, the classification is based on procedures for inducing simple responses and more complex ones.

The two response-induction procedures for simple responses involve shaping. Context shaping is used if the learner is capable of producing the desired response in some contexts but not in others. The context is systematically modified, from the one that the learner can perform into the targeted context. If the learner can answer a question such as, “What's your name?” only immediately following the answer to the question, this juxtaposition context is the starting point—the simplest context. Interruptions between presentations of “What's your name?” are systematically presented until the learner is able to perform when a great deal of interference and time is presented between presentations of the task, “What's your name?”

Form shaping is different. This technique is used if the learner is unable to produce the desired response in any context. The learner is able to produce only an approximation of the response. The shaping procedure involves establishing a criterion for reinforcing the learner so that the learner will be able to receive reinforcement for producing approximations that are as good as or better than those the learner typically produces. The criterion for reinforcing the learner shifts as the learner improves until the learner is reinforced for producing responses that are deemed appropriate.

The final response-locus category involves communications for complex physical operations (opening a door, tying a shoe, working a jigsaw puzzle, etc.). These operations involve parts that are to be chained together (in much the same way that a cognitive problem-solving routine chains parts or steps together to form a solution to the problem). The communication for inducing these operations is a program.

The key difference between these programs has to do with how they start. For the essential-response-features program, the first step may require the learner to perform the operation when the operation has been simplified. The first step for the enabler-response program requires the learner to produce the behaviors that are not essential to the outcome of the operation. The removed-component program initially presents practice in a context that is different from that of the operation.

Section II      Basic Forms

Section I presented the rationale for the stimulus-locus analysis, its relationship to the response-locus analysis, and an overview of the classification system that is based on common structural features of knowledge and skills. Section I provided a perspective of the major topics that will be dealt with in the following sections of this book.

Section II and the sections that immediately follow it shift from an emphasis on broad descriptions to a focus on specific how-to-do-it issues. The goal of these sections is to provide the degree of specificity needed for a person interested in creating faultless sequences to classify the concept being taught and to generate an acceptable sequence.

Chapter 4 provides a restatement of some of the facts and principles presented in Chapters 1 and 2. These principles are important because they apply to virtually all the communications that we will discuss. They indicate how to show samenesses, how to show differences, and how to test to
assure that the generalization has been transmitted to the learner.

Each of the remaining chapters in Section 2 deals with a specific type of basic-form communication. Chapter 5 presents procedures for creating non-comparative sequences; Chapter 6 deals with nouns; and Chapter 7 deals with comparatives.

The communications that are developed for the basic-form concepts in Chapters 5, 6, and 7 are initial teaching sequences, designed to show the learner what controls the concept being taught and how the examples of the concept are to be labeled. The communications do not indicate how to expand the concept and incorporate it in contexts other than the initial-teaching sequence.

These initial-teaching communications are quite close to being faultless. They are probably more faultless than many instructional situations require. However, if you understand how to construct these communications, you will have little trouble creating approximations that are not as intricate or carefully controlled. The value in studying the more faultless forms is that when the communication must be very precise, you will be able to respond to the situation. Also, fewer problems are created if the communication errs in the direction of providing too much information rather than too little.

The forms that we will work with serve as models of faultless presentations. They also serve as a basis for evaluating communications that are less than faultless.

However, there are alternative ways to present various concepts that may actually be preferable to the forms that we will develop. For example, if we wished to teach getting wider, our first choice would be a communication based on the sequence presented in Chapter 7. However, the teacher would have to follow it precisely. The potential of the communication would be achieved only if the teacher did what the sequence specifies to do. If the teacher did not appropriately time the presentation of each example and use the wording presented for the example, the communication might fail. If the teacher talked and moved the hand at the same time, the learner might not understand the relationship between the talking and the changes. The teacher must show the change; stop; and then produce the specified wording. Since these and other behaviors are highly relevant to the transmission of the communication, we must control them. We can do this by giving the teacher an elaborate list of do’s and don’t’s, by having a master teacher present the examples or by using the printed page. When we use the printed page, however, our examples must become static because we cannot readily use continuous conversion. Those details that are controlled so gracefully through continuous conversion must now be approximated through contrivances that exaggerate samenesses or differences and that provide for “relatively easy” comparison of examples. In the process, we make many compromises. Necessity usually dictates that we reduce the number of examples and deviate from the ideal in other ways. Often these deviations work reasonably well; however, they must be seen as “good solutions,” rather than the ideal.

Although single dimension non-comparatives, nouns, and single dimension comparatives are different in structure, they comprise the sensory-based concepts, generalizations or discriminations. We will use the terms concept, discrimination, and generalization interchangeably. A concept is a generalization to the appropriate range of examples. A generalization is not possible unless a discrimination is involved. (You cannot generalize something unless what you generalize is specific and different from other possible things that might be generalized.) The basic nature of a concept is a qualitative irreducible feature that makes the particular concept different from all others. If such qualitative structure cannot be identified, we can reduce the concept to another, simpler concept (or concepts). We can avoid possibly confusing discussions about the nature of concepts by referring to sets of examples. If a set of examples has an observable sameness, that sameness is a concept, the basis for a discrimination or a generalization.
As noted in Chapter 3, communications for sensory-based discriminations share these features:

The communication involves presenting concrete examples and labeling each. All positive examples receive the same response. Negative examples receive responses that are different. (The set of negatives may receive a single response, “No,” or a variety of responses, each different from the response used for positive examples.)

Examples of non-comparative single-dimension concepts include: horizontal, between, over, three, more than one, gradual, convex, curved.

Examples of nouns include: dog, factory, car, shoe, quotation mark, sentence, adverb, animal.

Examples of comparative single dimension concepts include: steeper, louder, hotter, faster, getting cloudier, becoming more intense.

The structure of the different concepts is summarized in Table II.1.

Both non-comparatives and comparatives are the same with respect to how positives and negatives are created. For both types, changes in a single dimension create the examples. For instance, positive examples of the non-comparative concept over are created by manipulating the position of the target object. By manipulating the position of the object, negative examples are created. For the comparative concept faster, changes in the speed of the object create positive examples, changes in the speed also create negatives. Nouns are “conjunctive” concepts, which means that an example is positive only if a number of features are present. For an object to be a shoe, it must have different parts, dimensions, relationships. We can change the object into a non-shoe by manipulating any of these dimensions or features.

The precision of the boundaries between positives and negatives varies considerably for the three types of sensory-based concepts. For single dimension non-comparatives, the boundaries are fairly precise; however, there may be some ambiguous examples. For instance, when is a stationary object over another object? Clearly, if the target object is in a “shadow” projected upward from the other object, the target is over. But what if the target is on the edge of this projection? Precisely when is it called over? The area of uncertainty for the non-comparatives is typically quite limited.

The boundary for comparatives is usually quite precise. Either something is louder, or not louder than another example of an audible signal. If we present the concept through sensory examples, we must make sure that the differences are perceptible through sensory observation. However, even if the differences are very small, the example is not ambiguous because the dividing line between positives and negatives is usually very precise for comparatives.

For nouns, the dividing line is very vague. When a shoe becomes a not-shoe is not known by knowledgeable adults because a precise dividing line does not exist and must become a matter of personal interpretation.

The three types of sensory-based concepts also differ with respect to the absolute value of the examples. The question that determines whether the concept is absolute is: Is a positive example of the concept always a positive example of that concept? For non-comparatives, the answer is, “Yes.” An example of over the table, is always an example of over the table. Also, an example of a noun, such as dog is always an example of dog. Comparatives, however, are different. “Is this line longer?”
The answer depends on the line to which the line is compared. The same line can be used as an example of longer and of not longer.

The structural samenesses and differences of these sensory-based concepts suggest structural samenesses and differences of the communications designed to teach them faultlessly. The sequences for teaching nouns must address the structural problem that nouns do not have a precise boundary between positive and negative examples. The sequences for teaching comparatives must somehow show that a given outcome (such as the line above) may be positive or negative.

Facts and Rules About Communicating Through Examples

When we teach a concept, we must communicate a message to the learner. Our communication must be unambiguous—consistent with only one interpretation—and complete enough to permit the learner to apply what has been taught to different situations. To achieve the teaching we present a series of examples that:

- Show the difference between positives and negatives.
- Show the range of positive examples.
- Provide a fairly thorough test of the learner’s understanding of the concept.

Facts About Presenting Examples

Basic cognitive teaching involves presenting the learner with some examples that will induce a generalization to other examples. There are logical facts about these communications with the learner and there are rules or principles for achieving different communication goals, such as showing how things are the same or how they are different.

The facts and principles will be illustrated by referring to sensory-based concepts that are shown by presenting concrete examples and labeling each example.

Fact 1. It is impossible to teach a concept through the presentation of one example.

The teacher presents a positive example of a concept by showing the object below and labeling it: “This is glerm.”

Glerm could refer to any feature of this example or any combination of features. Since the example has an enormous number of features, glerm could mean any one of an enormous number of things. The learner might select the right interpretation; however, the learner’s chances are not very good. Glerm could mean “horizontal,” “straight,” “pointed,” “made of wood,” “writing instrument,” “object with eraser,” “something that floats,” etc.

Fact 2. It is impossible to present a group of positive examples that communicates only one interpretation.

We can limit the number of possible interpretations by presenting positive examples only. This presentation may strongly imply the desired interpretation; however, a set of positive examples is always capable of generating more than one possible interpretation. Therefore the sequence of examples must contain negatives as well as positives.
Fact 3. Any sameness shared by both positive and negative examples rules out a possible interpretation.

The behavior that the teacher uses to signal positive examples is different from that used for negatives. Any sameness that is observed in both the positive and the negative examples, therefore, cannot account for treating the negative examples differently.

If we present example A as a positive example of flot and example B as a negative example of flot, any samenesses in the examples rules out possible interpretations.

The block is the same in both positive and negative example, therefore, flot cannot mean block. The horizontal orientation is the same in both examples, therefore, flot cannot refer to the horizontal orientation. Since any feature that is the same in both examples cannot be the basis for referring to one example as flot and the other as not-flot, the difference in behavior must be explained by reference to the features that are different from one example to another.

This fact about how negative examples rule out possible interpretations has great implications for teaching. To rule out a particular interpretation, we simply show the same feature in the positive example and a corresponding negative example.

Fact 4. A negative example rules out the maximum number of interpretations when the negative example is least different from some positive example.

If negative examples rule out possible interpretations, it follows that, the more samenesses shared by positives and negatives, the more interpretations the negatives rule out. The reason is that these negatives show that a greater number of features do not play a role in determining whether the object is positive or negative. Figure 4.1 shows negatives that are increasingly more like the positive:

Set A generates a number of possible interpretations, including: gloof means “being held in the hand”; gloof means “something with corners”; gloof means “higher than”; gloof means “dark.”

By changing the negative example (as in set B) so that it has more of the same features observed in the positive example, we can reduce the number of possible interpretations.

Some of the interpretations that were generated by set A are ruled out by the negative in set B. “Gloof” cannot mean block, because the block is present in both the positive and the negative. “Gloof” cannot mean dark, because darkness is a feature of both the positive and the negative examples. “Gloof” could mean higher than, or in the hand, or horizontally-oriented.

Set C rules out the interpretation that “gloof” means horizontally-oriented because the horizontal orientation is now in both the positive example and the negative example, and therefore cannot be the basis for determining what gloof is: “Gloof” could still mean being in the hand.

Set D rules out this interpretation by making being in the hand a feature of both positive examples and negative examples.

Set D generates only a few possible interpretations of “gloof.” Perhaps it means suspended. To clarify the precise meaning of gloof, we would need more examples—both positive and negative.
The fact about samenesses shared by positive and negative examples is important in designing communications. If we design a negative example so that it is highly similar to a positive example, we rule out the greatest number of possible interpretations. Only the difference between the positive and the negative can account for one example being positive and the other negative. Since there is only a minimum difference, that difference must be the basis for treating the examples differently.

In summary, the four facts indicate the basic ways that we can control the possible interpretations communicated through the examples by controlling the details of the examples. If we use a single positive example, we communicate an enormous range of possible interpretations. Additional positive examples rule out possible interpretations. For a feature to be the basis for a possible interpretation, that feature must be present in all positives. If it is present in only some, the feature cannot be a basis for classifying the examples as a positive. By presenting a wide variety of positives, we show which features are relevant to the concept.

Negative examples rule out possible interpretations when samenesses occur in both positives and negatives. For a feature to be the basis for classifying the example as positive, that feature must be present in all positives and in no negatives. Therefore, any feature that is present in a positive and in a negative cannot be the basis for a possible interpretation. The negatives that rule out the greatest number of possible interpretations are those that are least different from some positive. In this situation, the differences are few, so the range of possible interpretation is limited.

Juxtaposition Principles

The fact that a set of examples must be presented to convey a concept to the learner introduces a new variable—juxtaposition of the items. The examples that precede an example make that example relatively difficult or easy. There are five principles of juxtaposition. These are expressed as how-to-do-it rules.

1. The wording principle: To make the sequence of examples as clear as possible, use the same wording on juxtaposed examples (or wording that is as similar as possible).

By using the same wording with all examples, we assure that the learner focuses on the details of the example and is not misled by variations in the wording. If the wording presented with each example is the same, the learner is shown that each example is processed in the same way.

We can make an example more difficult by changing the wording on juxtaposed items. The sequence below makes this task relatively easy: “Say the last letter in the word hog.” Say the last letter in the word man. Say the last letter in the word dog. Say the last letter in the word hog.

To make the task relatively difficult, we precede it with a series of tasks that require the learner to perform a different operation. Here is such a sequence: Say the first letter in the word man. Say the first letter in the word dog. Say the first letter in the word frog. Say the last letter in the word hog.

This procedure is similar to that used in the game “Simon Says.” The leader presents a series of tasks in which he does the same thing he says. He then presents a task in which he does one thing and says another.

Easy juxtapositions are those in which the learner does the same thing with different examples,
because these juxtapositions do not require the learner to process as much information. The learner does the same thing with all examples.

2. The setup principle: To minimize the number of examples needed to demonstrate a concept, juxtapose examples that share the greatest possible number of features.

This juxtaposition principle deals with the examples in the same way the first principle deals with wording. The greater the number of variables shown in the juxtaposed examples, the greater the number of total examples needed to demonstrate a concept. If we teach under by using a dog or a cat that is under a table or chair, we need quite a few examples. We must show: The cat under the chair, the cat not-under the chair (on it, next to it, etc.), The cat under the table, the cat not-under the table, The dog under the table, the dog not-under the table, The dog under the chair, the dog not-under the chair.

To show each of these positions, more than one example would be needed.

If we increase the number of features shared by juxtaposed examples, we decrease the number of examples needed to demonstrate the concept. If we eliminate the cat and use only the dog, we are required to show only: The dog under the table, the dog not-under the table. The dog under the chair, the dog not-under the chair.

If we eliminate the chair, we are required to show only: The dog under the table, the dog not-under the table.

All juxtaposed examples contain the same dog and the same table. The only variable from example to example will be the relative position of the dog, which is the variable relevant to under.

The setup principle provides an easy formula for constructing the shortest, most efficient sequence: construct all examples so they share the greatest possible number of features. Not only will this formula permit us to demonstrate how the concept works with fewer examples, it will facilitate showing the learner which features are critical to the concept. If examples share the maximum number of features, they differ in the minimum number of ways. These are the ways that are relevant to the concept. The probability is therefore great that the learner will attend to the features and changes that are relevant to the concept.

3. The difference principle: To show differences between examples, juxtapose examples that are minimally different and treat the examples differently.

Positive and negative examples provide the maximum information when they differ only slightly from each other; however, positive and negative examples must be juxtaposed to guarantee that this information will be transmitted to the learner. Consider example set A in Figure 4.2. There are two minimally different examples created through continuous conversion.

When these examples are juxtaposed (one immediately following the other in time), the difference is conveyed relatively easily because the only change occurring from one example to the next is a slight change in orientation. When other examples are interpolated, however, the learner is not provided with a demonstration that shows this difference. Consider examples 1 and 4 in set B. They are the same examples that appear in set A. Although examples 1 and 4 are slightly different from each other and are labeled differently, the difference is not obvious because they are not juxtaposed.
When we juxtapose differently labeled examples that show the minimum difference, we call the learner’s attention to the fact that the small difference is the only basis for the change in labels.

4. The sameness principle: To show sameness across examples, juxtapose examples that are greatly different and indicate that the examples have the same label.

If we show under using only a table top and eraser, we can create many different positive examples of under. Some would be close to the table; others farther away; some would be near the middle of the table; others would be near the ends. The juxtaposed examples in Figure 4.3 show sameness. Note that the examples follow the wording principle (same wording for all examples), the setup principle (same objects appearing in juxtaposed examples), and the sameness principle (great difference from example to example with the same label from example to example).

Since juxtaposed examples are treated in the same way ("The eraser is under"), the changes from example to example are shown not to affect the label. The learner is told in effect, "These examples are the same, so whatever difference you observe in them is a difference that is irrelevant to under."

5. The testing principle: To test the learner, juxtapose examples that bear no predictable relationship to each other.

After the learner has been shown sameness and difference, the learner is tested on the generalizations implied by the communication. If the demonstration is adequate, the learner should be able to handle some new examples of the concept that are presented within the constraints of the setup principle. Note that the testing principle refers to the test that is provided immediately after the demonstration of sameness and difference. This test involves the same setup features as the sameness and difference demonstration. Following successful performance on this immediate test, the learner will be given expansion tests that involve new setups and new wording. The most immediate communication question, however, is: Did the learner receive the information needed to generalize to new examples presented within the original setup? The test that immediately follows the demonstration examples answers this question.

According to the testing principle, no pattern of responses should be evident from one test example to the next. (For example, no alternating sequence from positive to negative examples.) Examples presented in the test may be similar or dissimilar. The response called for by these examples may be the same or may be different. The test segment should repeat some examples that had been used to demonstrate difference and sameness. The segment should also contain new examples.

Applying the Five Principles

To provide a clear initial-teaching communication to the learner, we must design a sequence that takes into account all the facts and all five juxtaposition principles. The sequence must show relevant samenesses and relevant differences in the examples. The wording associated with the various examples must be precise. The setup must be designed to permit the smallest number of examples. And the learner must be provided with an immediate test, one that requires the learner to respond to examples created within the setup.

The sequence in Figure 4.4 is consistent with the five principles. As shown in Figure 4.4, different examples are designed to meet the requirements of different juxtaposition principles. The
sequence is a comparative sequence designed for the initial teaching of the concept, getting wider. Each example involves a space (diagrammed as a line with a marker at either end). To present the sequence above, hold your hands about a foot apart and say: “Watch the space.” Then hold your hands stationary and say the wording for example 1: “It didn’t get wider.” Move one hand in slightly, stop, and say the wording for example 2: “It didn’t get wider.” Move the same hand out slightly. Then say the wording for example 3: “It got wider.” Continue in this manner for the remaining examples.

Bracket A shows that the “same wording” is used for all examples. The wording could have been made even more uniform if the teacher demonstrated on examples 1 to 5 by asking the same question presented to the learner and then answering it: “Did it get wider? No....Did it get wider? No....” etc. The wording used in the illustration above is fairly uniform, however. All demonstration examples and all test examples refer to the same response dimension: getting wider.

Bracket B shows that all examples involve the maximum number of common setup features. Note that only one hand is involved in changing an example to the next example. (The same hand moves in all examples that involve movement.) The hands appear in all examples. The orientation of the hands, the background, and other features of the situation remain the same. Therefore, the setup principle is satisfied. The set of examples contains the maximum number of common features.

Bracket C shows that the difference is shown in two parts of the sequence. Both involve small differences in the juxtaposed examples that lead to different wording.

Bracket D shows sameness, created by juxtaposing examples that differ as greatly as possible within the constraints of the setup. Note that the size of the change from example to example is controlled for this concept because the communication must convey the idea that the size of the change has nothing to do with getting wider. The change from 2 to 3 is a very small change. The change from 3 to 4 is quite large. The change from 5 to 6 is intermediate. All are labeled in the same way: “It got wider.”

Bracket E shows the test juxtaposition, an unpredictable sequence that contains some minimum-difference examples and some greater difference examples. The test sequence attempts to avoid any pattern such as an alternating pattern of positive, negative, positive, etc.

Continuous Conversion

As noted earlier, the procedure by which you present the examples when you change one example into the next (e.g., holding your hands up and then moving one of the hands to create the different examples) is called continuous conversion. The use of continuous conversion forces you to create relevant changes in the examples. When you create examples through continuous conversion, you do not create total examples, only changes. The learner is therefore not required to attend to all details of the examples, merely those involved in the change. The fact that you must change examples in a way that changes positives to negatives means that you will create changes that are relevant to the concept.

To appreciate the difference in communication potential between continuous conversion and non-continuous conversion, present the sequence of examples for getting wider non-continuously. To do this, use exactly the same set of examples you used before. However, between each example, put your hands at your sides. Then put your hands up again to create the next example. Start with your hands about a foot apart. Say, “Watch my hands.” Put them at your sides. Raise
them to where they had been and say, “They didn’t get wider” (example 1). Again put your hands down. Return them, this time slightly closer together and say, “They didn’t get wider.” Continue through all examples in this manner.

The advantages of the continuous conversion sequence become immediately apparent when examples are presented non-continuously. It would be difficult for the learner to see that the space for example 2 is slightly less than that for example 1. The reason is that non-continuous conversion requires creation of all details for each example. First, all details of example 1 are created. Then all details of example 2 are created. To compare two examples, the learner is required to compare the two sets of details and observe possible differences. This task is logically more difficult than one in which the first example is changed into the next.

Continuous conversion makes small changes perceptible because one example is changed just enough to create the next example. If the two examples are highly similar, only a small change occurs; however, it is easy to detect because it is the only thing that happens.

Analyzing Concepts By Using Continuous Conversion

Continuous conversion of examples can be used to show us which dimensions are relevant to the concept. If we are in doubt about what causes an example to be positive or negative, we use continuous conversion to provide the answer. First we start with a negative example and, through continuous conversion, change it into a positive example. The dimension that we changed is a relevant dimension. (If we changed position, position is relevant; if we changed intensity, intensity is relevant, etc.) Next, we see how much change along the relevant dimension we can apply to a positive example without making it negative. We must operate within the constraints of the setup. For example, after observing that moving the hands in a certain direction causes an example to change from negative to positive, we conclude that movement of the hands is a dimension that is relevant to the concept. Next we see the extent to which we can move our hands without changing a positive example into a negative. This variation of the relevant dimension shows the range of positive variation that is possible within the constraints of the setup.

By applying the two-step conversion described above, we discover that many concepts are single-dimension concepts, which means that if we start with a negative example we can change it into a positive example only if we manipulate one dimension. We discover that other concepts are multiple-dimension concepts, which means that it is possible to change a positive into a negative by manipulating various dimensions.

Not all concepts can be presented through continuous conversion. If the example is the verbally presented statement, “The crow flew over the tree,” we cannot continuously convert that example into another verbal example. However, if we pretend that examples can be created continuously, we more readily see which changes are relevant to the concept, how the various examples are the same, and how they differ.

Perspective. The rules and principles presented in this section apply in some form to any instructional design problem, because all these problems start with some “need.” You want to show how things are the same or how they are different. You want to reduce the variables and make the relevant changes as obvious as possible. You want to test the learner on non-trivial generalizations of what you have taught. The principles apply because they are logical principles about examples.

Learn the principles of juxtaposition, and try to think of them as logical rules that apply to any situation that involves communicating through examples.
Summary

The most basic communications for teaching discriminations or concepts are ones that present examples and that permit the learner to perform on examples not shown in the initial presentation. Basic communication facts and principles are described in the context of communicating through examples. The facts deal with basic logical properties of communications that involve examples. The principles tell how to achieve particular communication goals, such as showing sameness, or showing difference.

The first fact is that the presentation of only one example cannot logically show one concept. The reason is that any concrete example is an example of thousands of concepts because it has thousands of features. The labeling of the concept does not indicate which features are being referred to. *

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