

The Learning-by-Doing Principle

Hayne W. Reese

West Virginia University

Abstract

Learning by doing has been a principle for thousands of years; it has had many proponents, including Plato, Thomas Hobbes, English and Spanish epigrammatists, Karl Marx and Mao Zedong, cultural anthropologists, Montessori, John B. Watson, and B. F. Skinner; and it has had many forms, including learning by doing, discovery versus instruction, practical experience versus book-learning, the practice-theory-practice dialectic, and proof upon practice. The paper includes discussion of several of the forms, with examples, to establish what the principle means; modifications of the principle such as instructed learning-by-doing and a role of reasoning; and possible explanations of its effectiveness.

Keywords

Practical Experience, Trial-and-error, Discovery, Practice-Theory Relation, Practice-Theory-Practice Dialectic

Learning by doing means learning from experiences resulting directly from one's own actions, as contrasted with learning from watching others perform, reading others' instructions or descriptions, or listening to others' instructions or lectures. Of course, watching, reading, and listening are actions, but they are not the kinds of doing referred to as learning by doing because they yield direct experience with demonstrations or descriptions of actions rather than with actions the learner actually performs. In classical psychology and its hangers-on (e.g., Robinson, 1930), "direct experience" meant mental contact with mental phenomena by introspection; but in the present context, it means sensory contact with the results of doing.

The learning-by-doing principle has been advocated widely and in many forms, including learn-by-doing, trial-and-error learning or discovery versus instruction, practical experience versus book learning, the practice-theory-practice dialectic, and "proof upon practice." The word practice in the last two of these versions is sometimes interpreted to mean repetition, as in a study by Keeling, Polacek, and Ingram (2009) discussed in the subsection "Learning to Ask Good Questions." However, it is intended in the sense of praxis, which means a goal-directed behavior. The phrase "goal-directed behavior" can be interpreted in a cognitive sense or in the sense of an operant behavior.

The learning by doing principle is old and many advocates have stated it as a truism. For example, it was cited without documentation by Sam Bonasso, a civil engineer, in an essay on creativity (Bonasso, 1983), and by the "semanticist, economist, and writer" Stuart Chase, in a book against communism and fas-

cism (Chase, 1938, p. 182; the quoted characterization of Chase is from Chase, 1969, unnumbered p. 217). Other examples of uses of the principle are discussed in the next section.

USES OF THE PRINCIPLE

The uses summarized in this section are organized by form or version of the principle. This approach is based largely on convenience, but some versions emphasize aspects of learning by doing that are only implicit in other versions.

■ DISCOVERY VERSUS INSTRUCTION

The first example in this section is more or less from everyday life. Another example of this sort is given in the section "Proof upon Practice."

TRIAL AND ERROR VERSUS READING A USER'S MANUAL

Trying to solve a computer or other mechanical problem by reading a User's Manual often leads to nothing but frustration, either because the manufacturer provides no hardcopy User's Manual or the one provided seems to have been written in a foreign language and badly translated into English or written in geek-jargon and not translated at all. Using trial and error with the computer keyboard and mouse often leads to problem solution, but this is not learning by doing unless the discovered process is remembered.

TRIAL AND ERROR VERSUS INSTRUCTION

Sidman (2010) commented that learning by doing can be errorful as in trial-and-error learning, or errorless as in insight and programmed errorless learning. Harlow's (1949, 1959) concept of learning set is relevant. It involved performing on a series of two-stimulus discrimination-learning problems each with a different pair of stimuli. The research showed that after a prolonged training series, subjects solve new problems in a single

Hayne W. Reese, Ph.D., Centennial Professor Emeritus, Department of Psychology, West Virginia University. This paper is an expanded and updated version of a paper presented at the meeting of the Association for Behavior Analysis, San Antonio, TX, May/June 2010, which was a shorter but updated version of an invited address presented at the meeting of the Nevada Association for Behavior Analysis, Reno, NV, October, 2009. Author's address: haynereese@aol.com

trial, whether the subjects are animals such as pigeons, rats, and nonhuman primates, or humans ranging from young childhood through old-old age and from below normal in intelligence to normal or better (for reviews, see Reese, 1963, 1964, 1989).

The occurrence of one-trial learning in this situation looks like insight, but only if one is unaware of or ignores the long training series in which the learning on each problem was by trial and error. Actually, at the end of training the one trial on which the new learning occurs can involve an error because the learning set provides no way to foretell which new object is correct. Therefore, the learning set can be described as Win-Stay, Lose-Shift: "Guess on Trial 1; if correct on Trial 1, choose the same stimulus thereafter, and if incorrect on Trial 1, choose the other stimulus thereafter." Normal human adults could presumably be taught the quoted sentence and might subsequently exhibit the learning set, but in this case the learning would be by instruction and the only insight involved would be realizing that the sentence is true.

Programmed errorless learning is a kind of instruction in that its effectiveness in eliminating errors depends not on the nature of the task but on the skill of the programmer. In the standard procedure, only the correct stimulus or only the incorrect stimulus is presented on the first trial or the first few trials of a problem, and then a choice trial is given with both stimuli. Research showed that errors occur on choice trials in the initial part of the series of training problems, indicating that the learning was actually not errorless.

In another procedure, often involving a single discrimination problem, the correct stimulus is presented alone at first and then the other stimulus is faded in before the choice trial. A typical finding is that some subjects make an error on the choice trial. A version of this procedure is being used when a complex behavior is taught by step-wise shaping of the behavioral units that compose it. Sidman (2010) commented that if the learner makes an error in a step, the teacher revises the "instruction." The learner is learning by doing in the sense that he or she is actually performing the behavioral units, but it is not real trial-and-error learning, it is learning by doing as instructed (discussed in the section "Role of Indirect Experience" and other sections cited there). The units are identified by a task analysis done by the teacher. According to my notes, Sidman said that any kind of trial-and-error learning would benefit from task analysis, and for trial-and-error learning in the usual sense, the task analysis should be done by the learner. The usual learner would need to learn how to do effective task analyses, and I suspect that this learning would most efficiently be learning by doing as instructed by an expert at task analysis.

This point is also applicable in "programmed instruction," which is like programmed errorless learning but in an educational context. The aim is to present the course aims and contents in a programmed form designed to allow students to learn on their own, at their own pace, with no errors, or a minimum of errors, and without lectures by an instructor. The effectiveness of the program depends on the program writer's skills not only in analyzing the aims and contents of a course but also in writing the steps that can lead students to learn by their own efforts. Cohen (1962) interpreted the method used by Socrates

and Plato as programmed instruction (he also cited two other interpretations).

A simpler, more direct version of the Socratic and Platonic method has been shown to facilitate problem solving. For example, Grote, Rosales, Royer, and Baer (in press) showed that 4-year-olds' sorting of multidimensional stimuli was facilitated by asking, "What are you looking for?" The question is content-free in that it does not refer to any specific dimension or set of dimensions that could be used as the basis for sorting; it seems to have been effective because it led the children to identify and then to name features that were bases for correct sorting. An example with more specific questions is a study by Lisina showing that young children's performance improved when the examiner asked task-relevant questions such as "How are you going to reach that?" and "What is broken?" The questioning led to greater organization and goal-directedness of the children's actions, presumably because it induced the children to identify an appropriate action or a relevant aspect of the situation (Zaporozhets, Zinchenko, & El'konin, 1971, pp. 214-215). Evidently, the questions in these examples, and in Socrates's and Plato's method, function as instructions. Therefore, these procedures exemplify learning by doing as instructed.

LEARNING THE DIALECTICAL METHOD

Kozulin (1984, p. 131) attributed the learning-by-doing principle to John Dewey; but although Dewey may have popularized it, it was known already by Plato. Plato believed that the way to learn "the philosophical method," by which he meant dialectic, is by using it (Annas, 1981, pp. 276, 292). In *The Republic*, Plato refused to answer young Glaucon's questions about the dialectical method because Plato thought it could be learned only by years of personal experience and practice (Plato, *The Republic*, Bk. 7 [532e-533a, 534], also identified as Pt. 3, chap. 27; 1941, pp. 253, 255).

RELATIONAL-FRAME LEARNING

A research example of discovery versus instruction is a study by Eikeseth, Rosales-Ruiz, Duarte, and Baer (1997) on stimulus equivalence in college students. Eikeseth et al. used instructions rather than training to establish the initial conditional associations, and then they gave symmetry and transitivity tests of stimulus equivalence with 16 interspersed probes of memory for the instructed associations. Only 28 of 58 subjects--about 48%--met a memory criterion of at least 15 correct responses on the 16 probes, and only 50% of the 28 exhibited stimulus equivalence by meeting the same criterion on the symmetry and transitivity tests. Eikeseth et al. said that 50% success is not bad in that it has also been found in the first set of probes when the initial conditional associations were learned by training rather than instructions. For documentation, Eikeseth et al. cited four reports, one covering two experiments. One of the cited experiments (Sidman, Kirk, & Willson-Morris, 1985, Exp. 2) included a normal adult, and his performance on the initial test trials--30% and 41% correct responses--was fairly consistent with the point alleged by Eikeseth et al. However, the other four experiments were irrelevant: three included no adults (Devany, Hayes, & Nelson, 1986; Lazar, Davis-Lang, & Sanchez, 1984; Sidman et al., 1985, Exp. 1) and one included children

and severely retarded institutionalized adults (Sidman, Willson-Morris, & Kirk, 1986). In any case, the learning-by-instruction approach Eikeseth et al. used is not as good as the learning-by-training approach, which involves learning by doing and allows the researcher to continue the learning-by-doing trials until the subject exhibits stimulus equivalence or can be inferred to be untrainable.

In another study, Eikeseth and Baer (1997) used learning-by-instruction and found that 26 of 36 subjects--72%--met the memory criterion, but none of the 26 met all the criteria for stimulus equivalence. They had expected this kind of result because the stimuli were meaningful and therefore had associations that could compete with the equivalence relations. The message I get from the two studies is that discovery is better than instruction for learning stimulus equivalence and perhaps all relational frames.

EDUCATION AND COGNITIVE DEVELOPMENT

The discovery versus instruction principle is a basis of Montessori's (1912/1964) educational methods. Using these methods, a teacher gives no formal instructions but equips the classroom with materials selected to encourage exploratory actions by the children that lead them to discover the principles that the teacher wanted them to learn. Soviet psychologists also endorsed the discovery versus instruction principle. For example, Pavel Blonsky recommended it as a method for school instruction (Kozulin, 1984, p. 131).

Discovery has also been a basic developmental principle, perhaps especially in dialectical theories. Examples are Piaget's cognitive psychology (e.g., Piaget, 1970) and Soviet psychology (e.g., Lisina, 1985, pp. 8-9).

■ PRACTICAL EXPERIENCE VERSUS BOOK LEARNING

BACKGROUND ON BOOK LEARNING

During the Scholastic era, much of philosophy was devoted to interpreting Aristotle's writings and using the interpretations to understand nature. Beginning in the Renaissance a primary aim of philosophy was to repudiate this book-learning kind of scholarship. For example, in 1651 Thomas Hobbes argued that the basis of true knowledge is learning from experience rather than book-learning (for references see the later subsection "Thomas Hobbes"). However, the fight has not yet been won. For example Marxist scholars, especially in the defunct Soviet Union, were still spending much of their time interpreting what were known as "The Classics," which were writings by Marx, Engels, and Lenin (Kamenka, 1967; Payne, 1968; Planty-Bonjour, 1967). The epitome of the continuation of the Scholastic tradition in the Western world has been Biblical scholarship, which by 427 C.E. already had an exegetical literature (Augustine, On Christian Doctrine, XXXIX Para. 59; 427/1958, p. 74).

PRACTICAL EXPERIENCE IN POLITICS

The German Marxist Karl Kautsky (1908/1953) endorsed the need for practical experience, and he attributed the principle to Rousseau (p. xii). Kautsky said that a participant in any act understands it better than a spectator does, and that a political

activist therefore has a better understanding of political history than does an historical scholar "who lacks the least practical acquaintance of what makes politics go" (p. xiii).

An example of Kautsky's point can be seen in an article by Ryan Lizza (2008) in The New Yorker. The article is about the history and current practices of selecting Vice Presidential nominees in the United States. Lizza discussed three practices that John Kerry identified, grouped roughly by when the candidates are selected: January, August, or October of the election year. The January selections are relevant here because the primary qualification is potential for helping the hoped-for new administration govern, and Lizza implied that this qualification reflects the need for practical experience. He said that the evidence of the required potential is usually "congressional experience and long Washington résumés," and as examples he mentioned Lyndon Johnson, Walter Mondale, George H. W. Bush, Al Gore, Dick Cheney, and Joe Biden. The needed expertness is knowing the inner workings of congress and lobbying by having been there and done that. In short, political experience in Realpolitik is more important than political theory. (Incidentally, for August selections the primary qualification is potential for helping restart a lagging campaign, and for October selections, potential for carrying a geographic or demographic group. Sarah Palin was the August type for John McCain; John Edwards was the October type for John Kerry.)

LANGUAGE ACQUISITION

Seventeenth century students at Harvard University were given theses written in Latin and were required to defend them in Latin. One of the theses in 1643 was, "Linguae foelicus usu, quam arte discuntur" (Morison, 1936, p. 583), which means "Languages are learned better by use than by formal rules" (Ong, 1958, p. 197, citing Morison). This principle is a truism now, but a challenge is presented in the subsection "Learning language by use."

LEARNING TO ASK GOOD QUESTIONS

Much research and a lot of theory indicate that learning is facilitated if the learner asks good questions (for a brief review, see Brill & Yarden, 2003). Keeling, Polacek, and Ingram (2009) wanted to study the effect of practical experience on the quality of questions generated by undergraduates in a real-life situation--a senior-level college biology course that included eight laboratory sessions. Before each laboratory session, each student was required to write at least three questions relevant to the session. A commentator in Science (MM, 2009) said that the quality of the questions improved over time, but actually the changes were statistically nonsignificant for the class as a whole, and for individual students the correlation between quality and time was statistically significant for only 3 of 38 students. The problem seems to have been inadequate feedback.

The authors said in their method section, "Brief marginal comments were written for feedback, discouraging lower-level questions and attempting to promote greater clarification and deeper thought" (p. 132). However, in their discussion section they said the results suggested that "learning by doing' is not enough . . . and that more explicit guidance and discussion may be required" (p. 138). They also said that asking good questions

had almost no consequences because full credit could be earned by asking almost any relevant questions and the grade for the questions accounted for only about 1.25% of the course grade. An implication discussed more fully in the subsection “Marxist version” is that feedback about unimportant consequences is ineffective and, conversely, important consequences are effective. The value of this statement can be questioned, because effectiveness is an observed property meaning that the desired behavioral change occurred, and importance is a conceptual property inferred from effectiveness. However, from the functional perspective of behavior analysis the concept of importance has the same epistemological status as the concept of reinforcement; therefore, the statement that important consequences are effective is analogous to the statement that reinforcement changes behavior. Nevertheless, like the relation between reinforcement and behavior change, the relation between importance and effectiveness is definitional rather than causal. Therefore, saying that importance causes effectiveness would be unjustified.

My conclusion is that practical experience without important feedback is mere repetition and is ineffective for learning by doing. That is, the proverb “Practice makes perfect” is wrong if practice means mere repetition, because repetition without feedback can make a habit stronger but cannot make it better (this point is supported in the subsection “Marxist version”). Therefore, learning to ask good questions is a version of learning by doing as instructed, which is discussed in the section “Role of Indirect Experience.” As such, learning to ask good questions is related to asking good questions to facilitate learning, which is discussed in the section “Trial and Error Versus Instruction.”

PRACTICAL EXPERIENCE IN OTHER DOMAINS

Claude Bernard (1865/1927, p. 15) argued that practical medicine should be based on experimental evidence and he said, rather ornately, that direct participation is needed: “We shall reach really fruitful and luminous generalizations about vital phenomena only in so far as we ourselves experiment and, in hospitals, amphitheatres, or laboratories, stir the fetid or throbbing ground of life.”

John B. Watson’s (1928) position was not so stringent. He said that literary authors need to have direct experience with their subject matter, but he added that authors can get their direct experience by observation rather than participation. That is, authors do not need to live the lives they observe, and indeed in some cases they should not live these lives. As an example, he said that being a reveler would interfere with clear observation of revelry. Although this example may support his point, the qualification--“in some cases”--correctly implies that the point is not universally applicable. An example might be the primitivist writer Jesse Stuart, who spent much of his life in the kind of rural environment in which his stories are set, perhaps accounting for his stories having an air of authenticity and veracity that made them popular even among highly urbanized readers (Foster, 1981). If, as I assume, he was an observer in the rural environment, he exemplifies Watson’s position; but he could have been a participant, thus exemplifying Bernard’s position.

The stance of Sergei Michailovich Tretyakov, a Russian poet, was more consistent with Bernard’s than Watson’s position. Tretyakov (1930) argued that “A close connection should be es-

tablished between author and subject,” which he said does not mean moving through the subject “like a tourist, ‘a respectful looker-on’” but actively participating in the subject (pp. 47, 48). In his own case, he established the close connection by becoming an active participant in a collective farm.

The American poet and Fascist sympathizer Ezra Pound (1931) said that Tretyakov’s position was not new: “There is nothing new for us in a writer’s living the life he writes of” (p. 124). However, Pound himself took a position closer to Watson’s than to Bernard’s and Tretyakov’s. As summarized by Walkiewicz and Witemeyer (1980), Pound’s position was that “the job of the Western writer is to observe his society, to communicate what he has learned about it, and to keep his art free from ideological bias” (p. 448).

■ THE PRACTICE-THEORY-PRACTICE DIALECTIC

ANALYSIS OF THE PRACTICE-THEORY-PRACTICE DIALECTIC

Marxist version. The learning-by-doing principle is seen in the practice-theory-practice dialectic, which is a basic principle in Marxist philosophy, theory, and application. For example, Karl Marx advocated and used it (1939/1973), the Soviet Union child psychologist Lev Vygotsky used it (1929, pp. 418, 431), and Mao Zedong popularized it in China (see inset quotation below). In this dialectic, “practice” means “doing,” not “repetition”; and “theory” is used in a broad sense that includes “knowledge” and “understanding.” The dialectic makes practice primary, like the doing in the learning-by-doing principle, and makes theory, knowledge, and understanding secondary because they are derived. This is a basic ordering in dialectical materialism.

Schram (1983) seems to have believed that Mao Zedong initiated the idea that practice is primary and knowledge is derived, but actually Marx initiated it (however, I believe the problem was in Schram’s wording rather than his belief). Petrović (1983) cited Marx’s third and eighth theses on Feuerbach on the origin (the theses are in Marx, 1845/1976). The gist of the third thesis is that conditions change human acts and are changed by human acts, and the gist of the eighth thesis is that social relations are practical in the “doing” sense. The eighth thesis is an explication of the seventh thesis--human characteristics are produced by social relations.

Petrović also cited a statement from the section “Private Property and Communism” in Marx’s Economic and Philosophical Manuscripts of 1844: “The resolution of theoretical contradictions is possible only in a practical way, only through the practical energy of man” (Petrović, 1983, p. 386). The italics are Marx’s (e.g., 1844/1975, p. 302). The statement was in a section that Marx crossed out, according to the editors, but evidently his crossing it out did not indicate that he rejected the idea; it is consistent with the theses on Feuerbach, which he wrote the next year. (Marx’s frequent use of italics reminds me of Little Orphan Annie’s in the comic strip written and drawn by Harold Gray. However, Marx’s excess can be excused because he was writing notes for his own use; Gray was writing for a readership. Gray’s stories, incidentally, were politically conservative morality plays [Horn, 1976, p. 459].)

Mao (1963/1968) stated the basic idea of the practice-theory-practice dialectic: Knowledge is at first perceptual, but sufficient accumulation of perceptual knowledge results in a dialectical leap to conceptual knowledge. This leap is one process in cognition, from objective matter to subjective knowledge. “Subjective knowledge” is a person’s (“subject’s”) knowledge, that is, an interpretation; but the first dialectical leap does not prove the correctness (truth) of subjective knowledge. Rather, correctness is proved by further practice, which is the practice-theory-practice dialectic. Mao (1937/1965) said:

Discover the truth through practice, and again through practice verify and develop the truth. Start from perceptual knowledge and actively develop it into rational [conceptual, theoretical] knowledge; then start from rational knowledge and actively guide revolutionary practice to change both the subjective and the objective world [i.e., the world as known and the actual world]. Practice, knowledge, again practice, and again knowledge. This form repeats itself in endless cycles, and with each cycle the content of practice and knowledge rises to a higher level. Such is the whole of the dialectical-materialist theory of knowledge, and such is the dialectical-materialist theory of the unity of knowing and doing. (p. 308)

The phrase “the unity of knowing and doing” does not contradict the primacy of practice over knowledge, cited earlier in this subsection. The relevant Marxist principle is “the struggle and unity of opposites” (for philosophical discussion, see, e.g., Planty-Bonjour, 1967, chap. 6; Wetter, 1958, Pt. 2, chap. 3, 1966, Pt. 1, chap. 5; for a brief overview, see Wozniak, 1972).

The inset quotation means that actual doing generates some knowledge, this knowledge leads to more effective doing, which generates improved knowledge, and the cycle continues until the doing attains its goal effectively and efficiently, that is, the cycle continues until the knowledge needs no further functional improvement. The cycle may seem to refer to practice in the sense of repetition; but it does not, because each instance of the doing is different from the preceding one. Furthermore, the differences are improvements in knowledge because they result from improvements in practice, which Mao explicitly said includes scientific experiments (1937/1965, 1940/1963, 1963/1968).

The cycle is like the Hegelian thesis-antithesis-synthesis trilogy, or negation of the negation, but with an historical necessity of improvement rather than Hegel’s logical necessity (for discussion see the subsection “Gap Between Practice and Theory”). The source of the historical necessity is feedback from practice; that is, knowledge changes because each doing in the cycle generates consequences that the doer observes. Therefore, feedback is an essential feature of the practice-theory-practice dialectic. This need for feedback supports the conclusion about the proverb “Practice makes perfect” in the subsection “Learning To Ask Good Questions.” Feedback is also needed because learning by doing requires not only doing something but also learning something from the doing. Learning requires some sort of feedback such as reward or punishment in stimulus-response learning theory and SR⁺ or SR in behavior analysis.

Other versions. Other versions of the learning-by-doing principle do not refer explicitly to theory, knowledge, or understanding,

but they implicitly require something of this sort. In stimulus-response learning theory, it is the concept of habit strength; in behavior analysis, it is the concept of the organism’s history of experiences with specified three-term contingencies; and in Aristotle’s theory it is hexis, which means potentiality in the sense of a person’s being able to perform an action that he or she is not performing right now. Hexis must be preceded by dynamis, which is potentiality in the sense of being able to learn a particular hexis (these are Aristotle’s typical uses of the two Greek words, but he sometimes used dynamis in both senses, e.g., in Aristotle, On the Soul, Bk. 2, chap. 5 [417a 21 - 417b 1]).

These versions demonstrate that Marxism is not the only possible basis of a practice-theory-practice kind of analysis. Like the learning-by-doing principle, it has had several different philosophical bases, and sharing the principle does not mean that these philosophies are compatible. An idealist example is Imre Lakatos’s (1978) philosophy that scientific progress has two forms, theoretical and empirical, and that a new scientific program can be theoretically progressive for a while by making stunning new predictions, but it will not survive unless it becomes empirically progressive by testing and confirming the predictions. Progress needs to be made experimentally, which means made via practice, as well as theoretically.

Lakatos erred on another point: He said that a theory is rejected if the stunning predictions are not confirmed. This assertion is consistent with Karl Popper’s falsificationism theory (1983, pp. xxi, 162, 244, 247-248, 342), which implies the silly notion that scientists do prediction-testing experiments in the hope that the predictions will be disconfirmed. Popper’s theory was that on the one hand, theories cannot be verified by confirming predictions, because the so-called verification would be the logical fallacy of affirming the consequent, but on the other hand, theories are falsified by disconfirmation of predictions, which is the valid argument of denying the consequent. Larry Laudan (1977, pp. 114-118) got the point right in arguing that when a prediction is disconfirmed, only a rival theorist rejects the theory. He also pointed out that proponents of the theory patch it up so that it provides a post hoc explanation of the anomalous observed facts without losing its prior explanatory value, and ideally the proponents then test the patched-up theory by testing predictions that it generates. This is what the practice-theory-practice dialectic means. It is also the standard procedure in behavior analysis: Start with a more or less vague idea or hunch, do research and see what happens, then do follow-up research to refine knowledge about the controlling variables, and the cycle continues.

NEED FOR TRANSFORMATION

Marx (1845/1976) expressed the need for practice in the sense of doing in his second thesis on Feuerbach: The truth of thinking is proved by practice, not by theory. He specified in the 11th thesis that the practice must change something: “The philosophers have only interpreted the world in various ways; the point, however, is to change it” (p. 8). The doing can be a conceptual analysis (i.e., a mental action) or a physical action. In both cases, the doing is transformative, either by transforming concepts or transforming things.

Conceptual analysis. When the doing is conceptual, the practice-theory-practice dialectic implicates Kaplan's (1964) "paradox of conceptualization": "Proper concepts are needed to formulate a good theory, but we need a good theory to arrive at the proper concepts" (p. 53). If "practice" is substituted for "theory," the relevance of Kaplan's paradox is more direct: The proper concepts are needed to formulate good practice, but we need good practice to arrive at the proper concepts. In a conceptual analysis, then, the development of theory, knowledge, or understanding consists of discovering through practice new significance--new empirical relations--of old concepts and dropping old concepts that have lesser significance in favor of new concepts that retain the old significance and promise to have new significance (expected to be revealed in further practice).

Marx (1939/1973, p. 100) used a conceptual analysis in developing *Das Kapital*: Such an analysis begins with a whole that is given concretely by experience; this whole is "chaotic" and it can be understood only by analysis. However, it is the psychological unit, and it can never be understood if it is also the unit of analysis. The needed units of analysis are the parts of the whole and their interrelations, but initially they are abstract conceptions rather than concrete experiences. Therefore, the analysis begins with identification of plausible conceptualized parts, continues with conceptual analysis of the whole into these parts and their possible interrelations, and then conceptually synthesizes the analytic parts and interrelations to create a new understanding of the whole. The process continues with better conceptualized parts and interrelations, and each new analysis and synthesis produces an understanding that is more coherent and less chaotic than the preceding understanding.

Physical analysis. Relevant to physical doing, Mao Zedong said, "If you want knowledge, you must take part in the practice of changing reality. If you want to know the taste of a pear, you must change the pear by eating it yourself" (1937/1965, p. 300). Juan Pascual-Leone, who is a Spanish-Canadian Marxist neo-Piagetian, also made the point, but not as concretely as Mao. Pascual-Leone (1976) said, "To know an object one must interfere with or act upon it; only in this praxis can the constraints of reality . . . create knowledge" (p. 112). Urie Bronfenbrenner attributed the same idea to his graduate-school mentor W. F. Dearborn: "If you want to understand something, try to change it" (Bronfenbrenner, 1977a, p. 284; 1977b, p. 538). I do not know whether Dearborn and Bronfenbrenner were Marxists, but the important point here is that the doing is not just looking at and observing things; it is active mental or physical manipulation that changes concepts or things. This point is examined in more detail in the section "Proof upon Practice."

Other views of transformation. In Pepper's (1942) analysis, organicism is the same as Hegel's philosophy, which was the dialectical idealism that Marx stood on its head when he created dialectical materialism. Dialectical materialism is consistent with Pepper's contextualism (Reese, 1993). Jean Piaget (1970) was an organicist, and he emphasized the role of transformation in the development of knowledge: "In order to know objects, the subject must act upon them, and therefore transform them: he must displace, connect, combine, take apart, and reassemble them" (p. 704). The rationale is that the transformations rule out al-

ternative interpretations of observed phenomena. Experimental methodology in science has the same form and rationale. The transformations are manipulations that change reality to create experimental conditions; the rationale is that by creating the experimental conditions, scientists rule out naturally occurring extraneous conditions as possible causes of the observed phenomena.

■ THE PRACTICE-THEORY RELATION

GAP BETWEEN PRACTICE AND THEORY

The authors cited in this section did not clearly distinguish between two meanings of "practice": practical application and transformative doing.

The philosopher of science Mario Bunge (1967) said:

The doctrine that practice is the touchstone of theories relies on a misunderstanding of both practice and theory: on a confusion between practice and experiment and associated confusion between rule and theory. The question "Does it work?," pertinent as it is with regard to things and rules, is impertinent in respect to theories. (p. 128)

A "touchstone" is "a test or criterion for determining the quality or genuineness of a thing" (Merriam-Webster's, 2002, p. 1243). Therefore, "practice" as the touchstone of theories is the transformative kind of doing; but Bunge's contrasting of "practice" and "experiment" and his associated contrasting of "rule" and "theory" implicate "practice" as practical application. Aside from being confused, Bunge was wrong because the question "Does it work?" is pertinent not only to practical applications and practical rules, but also to theories and transformative doings such as experiments. A theory "works" if it leads to predictions that are verified empirically, according to Lakatos, Popper, and Laudan; and a transformative doing or experiment "works" if it confirms expectations or predictions or disconfirms them but leads to plausible patching of the underlying theory (subsection "Other versions").

Brandtstädter (1980) said, "no logical tracks lead from theory to practice and back again" (p. 16). He was right whichever sense of "practice" is used, but only because the relation between theory and practice in either sense is not a logical relation. Kemp (1992) expressed this point with respect to practical application in saying that engineering at its best is not applied science, it is an art form. Any relation between practical application and theory is empirical rather than logical because a scientific theory does not necessarily have any implications about practical application and vice versa. As in the Marxist practice-theory-practice principle, the relation between transformative doing and theory is dialectical. As a Marxist concept, this dialectical relation is true by historical necessity, that is, it is necessarily true because it is what occurred in fact (Engels, 1894/1987, p. 124; Hook, 1950/1962, p. 68). In this respect, as mentioned in the subsection "Marxist version," it is different from Hegel's triad of thesis, antithesis, and synthesis, which is a logically necessary progression in Hegel's dialectical idealism (Hegel, 1830/1892, chap. 9; Hook, *ibid.*). (A parenthetically noteworthy point is that Marx often said that the dialectical relation is a necessity, most notably in his and Engels's Manifesto of the Communist

Party [Marx & Engels, 1888/1955, pp. 31, 32] but also elsewhere [Marx, 1852/1983, pp. 62, 65, 1875/1989, p. 95]. However, he was not asserting any logical necessity in dialectical materialism, he was talking about past and expected future historical necessities in historical materialism.)

SUCCESS IN APPLIED PRACTICE

“Practice” in this section means practical application in the real world, as in “medical practice.” Baer (1981) said that theory and the basic research it generates enable successful practical application but do not guarantee it, and practical application can be successful even if the enabling theory and basic research are unknown to the practitioner. For example, the art of photography was made possible by basic knowledge about optics, the physical mechanics of cameras, chemistry, and so on, but a photographer does not need this knowledge in order to be successful. Furthermore, as Baer said, to get good pictures of a wedding one hires a photographer, not an optics researcher, and to get treatment for an ailment one goes to a physician, not a physiologist. Preferably one goes to an expert practitioner, but knowledge about a practitioner’s practical expertness is sometimes hard to get.

Baer’s point that practitioners can be successful without relevant book learning means that their successful practice must have come from direct experience. These practitioners would begin as uneducated novices, and being uneducated, they would need to get the knowledge required for successful practice either by using a trial-and-error method to get the direct experience that would generate this knowledge, or by using the method of learning by doing as instructed by an expert practitioner (this method is discussed in the section “Role of Indirect Experience”). A problem with the first method is how the novices could recruit persons to be subjects of the trial-and-error work. Who would volunteer to be subjects of trial-and-error work by a would-be surgeon, or even a would-be professional wedding-photographer?

Juan Huarte solved this dilemma in the 16th century by explaining why theory is needed:

To what end serveth it to spend time in schooles? to this may be answered, that first to know the art of phisicke is a matter verie important: for in two or three yeares, a man may learn al that which the ancients have bin getting in two or three thousand. And if a man should heerin ascertain himselfe by experience, it were requisit that he lived some thousands of yeeres, and in experimenting of medicines, he should kill an infinit number of persons before he could attain to the knowledge of their qualities: from whence we are freed, by reading the books of reasonable experienced phisitions. (Huarte, 1594/1959, p. 181; orthography modernized; spelling and punctuation unchanged)

Consequently:

The perfection of a phisition consisteth of two things The first is, to weete [i.e., know] by way of method, the precepts and rules of curing men in generall, without descending to particulars. The second, to be long time exercised in practise, and to have visited many patients: for . . . there rest in them particularities of such condition, as they can neither be delivered by speech, nor written, nor taught, nor

so collected, as that they may be reduced into art: but to know them, is onely granted to him, who hath often seen and had them in handling. (pp. 174-175)

That is: Book-learning or theory deals with universals, which are abstract, and practice deals with particulars, which are concrete. Therefore, book-learning is insufficient by itself because it is uninformative about regularly successful practice, which requires knowing and dealing with the relevant particulars of each different person. However, direct experience is also insufficient by itself because although it deals with particulars, life is too short for direct learning of all the particulars that are relevant to successful practice. Therefore, effective practitioners base their procedures not only on extensive practical experience but also on theoretical principles. The theoretical principles are learned from books written by well-experienced prior practitioners; the practical experience permits implementing the principles in ways that are effective in particular cases such as a physician’s curing a particular ailment in a particular person. The basic message I derive from Huarte’s discussion is that theory is a distillation of previous persons’ direct experiences and it is needed to guide present seekers of direct experiences.

SUCCESS IN SCIENTIFIC PRACTICE

The message I drew from Huarte’s discussion of the relation between theory and applied practice is also relevant to the relation between theory and practice as transformative doing in science. However, some commentators have emphasized the fact that theory can have scientifically undesirable effects. For example, Farrington (1961, p. 207) said, “If he [a scientist] has a theory he tends to see what supports it and to miss other significant facts.” Lillard (1999, p. 57) made a point consistent with Farrington’s: “People respond not to the world as it is, but to the world as they believe it to be”--“belief drives action.” Skinner (1980) went further:

[Models] evoke contemplation rather than action. The theoretical physicist wants to represent reality; the laboratory physicist wants to do something about it. One changes a model to produce a different picture; the other manipulates independent variables to change a dependent variable. A model is what something is to be done about; it is not what is to be done.

Model is little more than another word for idea--something known by acquaintance. I look forward to greater recognition of the importance of laboratory scientists. The theorists have been sponging on them for decades and getting most of the credit. (pp. 173-174)

Even granting all this, the consensus supports extending Huarte’s message to science: Theory is needed as a guide for direct experience in the form of research. James Mark Baldwin (1895) made the point, a little effusively:

That most vicious and Philistine attempt in some quarters to put psychology in the straight-jacket of barren observation, to draw the life-blood of all science--speculative advance into the secrets of things--this ultra-positivistic cry has come here as everywhere else, and put a ban upon theory. On the contrary, give us theories, theories, always theories! . . . In the matter of experimenting with children,

. . . our theories must guide our work. (p. 38)

Others have made the point without the effusion. (a) Pasteur said, “Without theory, practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention” (Vallery-Radot, 1923, p. 76) and “Progress with routine is possible, but desperately slow” (p. 146). (b) Kantor (1953, p. 20) said, “Hypotheses, laws, or theories . . . are very often the most effective instruments for discovery and measurement.” (c) The Soviet psychologist S. L. Rubinshteyn (1955/1957, p. 265) said, “Experimental investigation is blind unless its course is illumined by theory.” (d) Farrington (1961, p. 207) said, “In the infinite variety and complexity of the phenomena of nature the scientist is at a loss in which direction to turn unless he is looking for something. If he is looking for something, that means he has a theory.” (e) Lewis (1966, 1988) said that theoretical work is foremost because nontheoretical research is “inscribed (trivial, limited)” (1966, p. 72).

■ “PROOF UPON PRACTICE”

The “proof upon practice” proverb means that proof in the sense of a test of truth is given by practice in the sense of one’s own action. One version of it, not discussed herein, is the “successful working” truth criterion of contextualism (Pepper, 1942; Reese, 1993); four other versions are discussed in the following subsections.

“PROOF UPON PRACTICE” VERSION

The 16th century English epigrammatist John Heywood seems to have created the “Proof upon practice” version of the proverb, although its meaning was older. He described it in the following lines from a longer poem:

Practise in all, above all toucheth the quick.

Proof upon practise, must take hold more sure

Than any reasoning by guess can procure.

If ye bring practise in place, without fabling,

I will banish both haste and busy babling. (1562/1966, p. 15; his italics)

“Babbling” is an old, now obsolete version of “babbling” (Oxford, 1989, p. 850); one meaning, which I think is the one Heywood intended, is foolish or meaningless talk (Oxford, p. 848). Heywood apparently used the italics to identify proverbs that he was attempting to explicate by weaving them into a story, and in this quotation their sense is carried by his phrase “proof upon practise,” that is, truth is tested by practice, not by reasoning.

“PROOF OF THE PUDDING” VERSION

According to an English proverb, “The proof of the pudding is in the eating” (Magill, 1965, p. 805); that is, the test of truth is in a relevant action. Stevenson (1967, p. 515) attributed this proverb to in No. 567 of *The Spectator* and to Henry Glapthorne in Act 3 of *The Hollander*. Addison called it “a homely Proverb” (1714, unnumbered p. 2), indicating that he did not originate it. In Glapthorne’s (1635/1874) play the character *Sconce*, who is the Hollander, has bought a “weapon salve” that purportedly can cure wounds without surgery and he questions its efficacy,

saying “The prooffe of a pudding is the eating” (p. 116). Tilley (1950, p. 558) did not cite Addison, but he cited Glapthorne, two uses earlier in the 17th century than Glapthorne’s use, and eight uses later than Glapthorne’s.

The “proof of the pudding” proverb has also been attributed to Cervantes in *Don Quixote* (Bartlett, 1980, p. 169; Stevenson, 1967, p. 1621), but the attribution is not strictly correct. The proverb was used in a 1700 translation of *Don Quixote* into English, as a substitute for the Spanish proverb “It will be seen in the frying of the eggs” (Magill, 1965, p. 805), which is discussed next. (Bartlett and Magill attributed the translation to Peter Motteux. Bartlett cited Part 4, chapter 10, page 322 in what he called a Modern Library Giant edition, without citing a year. A 1950 edition published by “The Modern Library” contains the pudding proverb at the location Bartlett cited; this edition is a 1719 revision by John Ozell of Motteux’s translation [Doyle, 1950, p. vi], and an editorial note on page 322 indicates that the pudding proverb was substituted for Cervantes’s frying-eggs proverb. Therefore, Bartlett should have known that his attributing the pudding proverb to Cervantes was incorrect. The Modern Library published another translation in 1949, by Samuel Putnam. Putnam [1949] said that critics called the Motteux translation “odious,” “worse than worthless,” and “the very worst” [pp. x, xii-xiii]; he said the Ozell revision was in 1725 [pp. xii, 1037]; and he cited a 1930 Modern Library publication of the Motteux-Ozell translation [note 18, p. 466; p. 1037]. He used Cervantes’s frying-eggs proverb [Cervantes, 1949, Part 1, chap. 37, p. 335]--“you will see when you go to fry the eggs”--and he indexed an unhelpful end-note, in full it was: “5. A proverb” [p. 483]. Stevenson cited Part 2, chapter 24 in no specified edition, but this chapter is not relevant in any edition I have seen, including a facsimile of the 1605 Spanish edition [Cervantes Saavedra, 1605/1905].)

“FRYING EGGS” VERSION

The meaning of “proof upon practice” is expressed in a 15th century Spanish proverb about knowledge based on discovery: “It will be seen in the frying of the eggs” or “On frying the eggs you will see.” Cervantes used this proverb in *Don Quixote* (Part 1, chap. 37; the “It will” version is from Cervantes Saavedra, 1605/1905, p. 322; the “On frying” version is my translation of “Al freir de los huevos lo verá,” *ibid.*, spelling modernized). Fernando de Rojas used a version without the eggs in 1499 in *La Celestina*--“Al freyr lo verá,” “On frying you will see” (Rojas, 1499/1913, p. 39; my translation). However, as indicated in the third context described below, the eggs were implicit in his version.

Three main contexts have been used to explain the proverb. The most popular one was given by, for example, the editors of two English translations of *Don Quixote*: A robber stole a frying pan from a house and the mistress of the house saw him and asked him what he had. He answered, “On frying the eggs you will see” (Cervantes Saavedra, 1932, note 2, p. 422) or “you will know when your Eggs are to be fry’d” (Cervantes, 1950, note *, p. 322). Iribarren cited a somewhat different context that had been given in 1574:

Melchor de Santa Cruz, in his *Floresta española de apotegmas* [Collection of Fine Spanish Aphorisms; my translation], published in 1574 (chap. 5, story 10), says thus:

“A charcoal merchant sold a basket of charcoal to a woman, and took a frying pan that was poorly guarded, and put it in the empty basket. Upon the woman’s asking him if the charcoal was of oak, and if it was good, he said, “On frying the eggs you will see.” (Iribarren, 1955, p. 123)

The third context was given in the 1950 edition of *Don Quixote* cited above: “When Eggs are to be fry’d, there is no knowing their goodness till they are broken” (Cervantes, 1950, editor’s note *, p. 322). Cejador gave this context more fully in a comment about the line quoted above from Rojas’s *La Celestina*:

On frying the eggs you will see is another version (Don Quixote, Part I, chap. 37). On frying the eggs is when one sees what they are; in the event, things become known. Eggs that are soft-boiled or scrambled can pass as good; but not so those that are fried, because the yolk is entirely visible. (p. 92 in Cejador’s note 15, in Rojas, 1499/1913; my translation)

(Iribarren also cited Cejador’s comment.) This context legitimizes the substitution of the “proof of the pudding” proverb for the “frying eggs” proverb. The substitution would be “The proof of the pudding is in the eating” for something like “The test of the egg is in seeing the yolk.”

A MODERN VERSION

Skinner (1945) gave a modern version of “proof upon practice”:

The ultimate criterion for the goodness of a concept is not whether two people are brought into agreement but whether the scientist who uses the concept can operate successfully upon his material--all by himself if need be. What matters to Robinson Crusoe is not whether he is agreeing with himself but whether he is getting anywhere with his control over nature. (p. 293)

That is, “the scientist” does not use the mechanistic criterion of truth by agreement, but rather uses proof upon practice, which as noted above is the contextualistic truth criterion of successful working. In Skinner’s statement, the phrase “operate . . . upon his material” refers to a doing kind of practice, and the adverb “successfully” and the “getting anywhere” clause refer to proof.

CHALLENGES OF LEARNING BY DOING

■ Pervasiveness Is Not Relevant

The pervasiveness of the learning-by-doing principle implies that it is more effective than other methods of learning, such as direct instruction; but it equally implies nothing more than that the principle is believed to be more effective. Empirical evidence is troublesome because any one condition can be found to be superior to a comparison condition if the comparison condition is selected for its known or presumable inferiority. Of course,

using this device violates one of the canons of science, stated with some euphoria in 1841 by the astronomer John Herschel:

Another character of sound inductions is that they enable us to predict. We feel secure that our rule is based on the realities of nature, when it stands us in the stead of new experience; when it embodies facts as an experience wider than our own would do, and in a way that our ordinary experience would never reach; when it will bear not stress, but torture, and gives true results in cases studiously different from those which led to its discovery. (p. 233)

A problem is that even if the strategy is used consistently with Herschel’s canon, it is not necessarily sufficient, because research methods can be more subtly flawed. The anthropologist L. Marano (1982) said, “Exposure to primary data source opportunities does not often lead to valid conclusions when inadequate research strategies are employed” (p. 395).

When definitive empirical evidence cannot be obtained, the only alternative strategy may be to use theoretical evidence. In the present case, the evidence would come from a persuasive theory about why learning by doing is effective. I address this issue in the last section. Theory also has another role, discussed next.

■ ROLE OF THEORY

As indicated in the section “The Practice-Theory Relation,” a problem with the learning-by-doing principle is that the doing needs to be guided: Doing, or practice in general, always has an effect--even if only a small or trivial one--and therefore practice is always some kind of efficient cause. However, as Hegel (1830/1892, p. 344) said, efficient cause is blind without final cause. Or as stated in a Soviet manual, *Fundamentals of Marxism-Leninism*, “unguided by theory, practice is doomed to grope in the dark” (1st ed. 1961, p. 114; 2nd ed. 1963, p. 94). The negative “unguided by theory” implies that practice should be guided by theory. This implication is verified in a later version: One function of theory is “to point the way ahead to new knowledge” (*Fundamentals*, 1982, p. 181). That is, theory should function as a purpose of practice, and as a purpose it has the functions--but not the nature--of a final cause.

■ ROLE OF REASONING

John Heywood’s (1562/1966) comment about “reasoning by guess” (in the subsection “Proof upon Practice’ Version”) is relevant here. He did not mean that reasoning is irrelevant to proof upon practice, but that reasoning without practice is “busy babbling.” The role of reasoning was also discussed by 17th century authors.

THOMAS HOBBS

In 1651 in *Leviathan*, Thomas Hobbes endorsed a kind of learning by doing in which scientists’ knowledge is based on facts they obtain directly rather than by revelation or the authority of books. His spin on the principle was that scientific knowledge does not come directly from the directly obtained facts, it comes from reasoning about these facts. He excluded reasoning based on “supernatural revelation” and “the authority of books,” and

the kind of knowledge reflected in “prudence,” or “foresight,” which is based on experience but not reasoning (Hobbes, *Leviathan*, Part 1, remarks in introductory chap., which is chap. 46 in Part 4 of the original work, 1st, 2nd, 4th, and 5th paragraphs; re “foresight,” chap. 3, paragraph marked *Prudence*, see also chap. 5, penult. paragraph; re role of reasoning, chap. 5, *ibid.* and paragraph marked *Science*; re “science,” chap. 9, chart; 1651/1958, pp. 3-4 in intro. chap., pp. 34-35 in chap. 3, 49-50 in chap. 5, 76-77 in chap. 9).

Hobbes also said:

*Men that take their instruction from the authority of books, and not from their own meditation [are] as much below the condition of ignorant men as men endowed with true science are above it. . . . For words are wise men's counters, they do but reckon by them; but they are the money of fools that value them by the authority of an Aristotle, a Cicero, or a Thomas [Aquinas], or any other doctor whatsoever, if but a man. (Hobbes, *Leviathan*, Part 1, chap 4; 1651/1958, pp. 41-42; bracketed “Aquinas” is editor's insertion)*

He that takes up conclusions on the trust of authors, and does not fetch them from the first items in every reckoning, which are the significations of names settled by definitions, loses his labor; and does not know anything, but only believes. (chap. 5; p. 46)

When I read these statements, I wondered why I was reading Hobbes's book; but then I realized that I was reasoning from what he had written rather than accepting his authority. An implication is that book learning can be a useful substrate for reasoning. This implication is consistent with the point of the preceding section.

S. DE COVARRUBIAS OROZCO

In 1611 Covarrubias gave reasoning a role in discovery in his interpretation of the “frying eggs” proverb discussed in the subsection “Frying Eggs’ Version.” He said:

This proverb gives us to understand that if we are not prepared with enough time to avoid haste, and we are advised of the absence of something that is needed for attaining our end, we should take the council of the sage and wise and when the event comes, we will notice the absent thing that we are accustomed not to think of. (1611/1943, p. 668; my translation)

The basic point is still knowledge through discovery, but specifically in cases where the absence of reasoning makes a person unlikely to detect the missing object because the object's *presence* is too commonplace to be noteworthy. Benjamin Whorf (1940/1956) also discussed cases like this and gave the examples of “not missing water till the well runs dry, or not realizing that we need air till we are choking” (p. 209).

■ ROLE OF INDIRECT EXPERIENCE

A preliminary point is that in this section the basis of learning has shifted from *doing* to *direct experience*. This is a standard shift; for example, Peláez and Moreno (1998) used it in a distinction between rules provided by others and self-generated rules, which are generated by one's own direct experience. I discuss an

implication of this shift in the section “Self-Shaping”; the aspect relevant here is the converse, learning from *indirect* experience.

The learning-by-doing principle implies that laboratories of science are useful because they permit direct experiences by doing, but scientific journals, books, and lectures are not useful because the only doings they require are reading or listening and then comprehending and remembering. These doings yield only indirect experiences with their topics. Therefore, only the elite, the few with direct experience, can truly understand phenomena.

A counterargument is that although direct experience is necessary, it can be acquired indirectly. The point is expressed in a Latin proverb, “What should be done must be learned from one who does it” (quoted from Davidoff, 1946, p. 101). This proverb means learning by doing as instructed, which is discussed here and at least mentioned in the sections “Trial and Error Versus Instruction,” “Learning To Ask Good Questions,” “Success in Applied Practice,” “Errors by the Founder,” and “Learning language by use.”

Thomas Huxley implicitly referred to this point in a speech on technical education that he gave in 1877 to the Working Men's Club and Institute in Britain. He had described technical education as “the teaching of handicrafts” (1877/1882, p. 74; his quotation marks), and he said that “many of you” might well wonder “What does this speaker know practically about this matter? What is his handicraft?” (p. 75). He then devoted about two and a half pages to arguing that in his scientific specialty, which was anatomy, he did intricate dissections that required him to be a handicraftsman. I do not think he established his credentials as a handicraftsman, especially because of two further comments: (a) The formal education of boys who will become working men, or handicraftsmen, should end “as early as . . . at present” (p. 82) to allow them to engage in learning their handicraft. In that era, these boy's formal education ended at the age of 13 or 14 years (p. 86). (b) Consistently with the principle of learning by doing as instructed, he said, “The workshop is the only real school for a handicraft” (p. 80). The initial workshops for anatomical dissections probably included work on animal and human cadavers, perhaps animal vivisection, watching experts do operations on live humans, and their own supervised doings of such operations. This sequence involves the method of learning by doing as instructed by relevant experts.

Mao Zedong directly referred to the point under consideration:

All genuine knowledge originates in direct experience. But one cannot have direct experience of everything; as a matter of fact, most of our knowledge comes from indirect experience. . . . [However], what is indirect experience for me is direct experience for other people. Consequently, considered as a whole, knowledge of any kind is inseparable from direct experience. All knowledge originates in perception of the objective external world through man's physical sense organs. Anyone who denies such perception, denies direct experience, or denies personal participation in the practice that changes reality, is not a materialist. (1937/1965, p. 300)

(The phrase “is not a materialist” was a polite way of saying “is an idealist,” which is anathema to a Marxist.)

■ EXCURSUS ON THE INDIRECT EXPERIENCE PRINCIPLE

The alleged role of indirect experience is not necessarily a serious challenge to the learning-by-doing principle because the indirect experience principle also has problems. Four kinds of problems are discussed in the present section.

DISTANCE FROM DIRECT EXPERIENCE

As indicated in the inset quotation above, Mao Zedong assumed that another person’s direct experience can substitute for a person’s own direct experience. A problem with this formulation arises when the direct experience is at the beginning of a chain of tutors passing their indirect experiences to their pupils who in turn become tutors, and the chain is probably often long and increasingly separated from the direct experiences that founded the chain. The problem is that each pupil’s direct experience is not with what the tutor learned, but with the tutor’s words or actions, and as the chain becomes longer, the words or actions might reflect less and less well what the founder had learned by direct experience.

ERRORS BY THE FOUNDER

Another problem is that even the founder might convey knowledge poorly. For example, in the standard procedure for instructing ballet dancers, the choreographer’s instructions consist largely of demonstrating the desired movements by performing them, then leaving while the dancers practice what they remember having observed, and then returning and critiquing their performances verbally and with further demonstrations. An anecdote about the ballet dancer and choreographer George Balanchine provides an example. He instructed his dancers almost entirely by performing the movements he wanted. Taper (1960) described the process:

*What a ballerina may pick up from watching Balanchine dance her part for her is a heightened awareness of her own special style and qualities, which his keen eye has perceived, and which he has rendered in clarified form for her. Still, there is no denying that all his dancers are acutely responsive in copying and appropriating the qualities he sketches out in dance for them. An instance of just how responsive they are occurred when he was choreographing *Bourrée Fantasque* a number of years ago. When he had the ensemble repeat for him a section that he had created the preceding week, he was perplexed to see that all the movements were being danced in a peculiarly cramped and agonized way. When he questioned the dancers, they insisted that this was the way he had shown the steps to them. He could not figure it out until he recalled that the week before he had been suffering from bursitis; the company had apparently picked up all his aches and pains and magnified them into a bursitic *Bourrée Fantasque*. (Taper, 1960, p. 23)*

In terms of the present analysis, Balanchine deliberately used doing for instruction, the dancers deliberately imitated what

they had seen, and they based their imitations largely on what they had already learned by doing. The rehearsal hall is lined with mirrors and the dancers watch themselves and practice until their movements accurately imitate what they remember seeing. That is, their indirect experience of watching Balanchine’s performance-as-instruction became their direct experience of monitoring their own performance.

This example shows that learning by indirect experience can include deliberate verbal or motoric instruction, incidental modeling, and learning by doing. The learning-by-doing aspect involves direct experience with one’s own deliberate and automatic doing in attempting to reproduce a model’s demonstrations. An important point here is that this learning by doing is not learning by imitating, because learning by imitating is learning by observing someone else’s action. As indicated in the example, learning by imitating becomes learning by doing when the learner learns by directly observing his or her own action. However, it is not pure learning by doing; it is learning by doing as instructed or modeled (discussed in the section “Role of Indirect Experience”).

LIMITED SCOPE

A preliminary point is that learning by indirect experience such as watching, reading, listening, and imitating, may be less effective than learning by doing, but it is certainly more efficient as far as it goes and for many purposes it goes far enough (see the section on science education in the April 23, 2010 issue of *Science*, Vol. 329, and letters to the editor in the August 13, 2010 issue). An example is solving problems with a word processor by reading a good user’s manual, such as *Power Point 2003 Just the Steps for Dummies* (Obermeier & Padova, 2006). Nevertheless, the learning-from-indirect-experience argument is not convincing in some cases. I describe four cases in the following paragraphs.

An animal analogue. One case is a study by Held and Hein (1963) on the development of visually guided behavior in kittens that were reared in darkness and then were given visual experiences. The kittens were paired and the kittens in a pair received highly similar visual experiences in the apparatus shown in Figure 1. One kitten received varying visual stimulation that it actively produced by walking in both directions, stooping, and rearing. The paired kitten received the same varying visual stimulation passively, by riding in a gondola yoked to the first kitten’s movements by the chain across the top, the bar, and the pivot (the cylinder on the bar is a moveable counterweight). Head movements also provide varying visual stimulation, but the active kitten’s head movements were not transmitted to the passive kitten, and its head movements were not controlled and therefore provided unyoked, independent variations in visual stimulation. The findings indicated that the active kitten developed normal vision, but the passive kitten did not until it was allowed 48 hours of unrestricted activity in a lighted room. Evidently, normal visual development requires actively produced variations of visual stimulation, and merely looking at scenery that happens to change is not sufficiently active to be effective. Analogously, in humans watching, reading, listening, comprehending, and remembering are not sufficiently active kinds of doing.

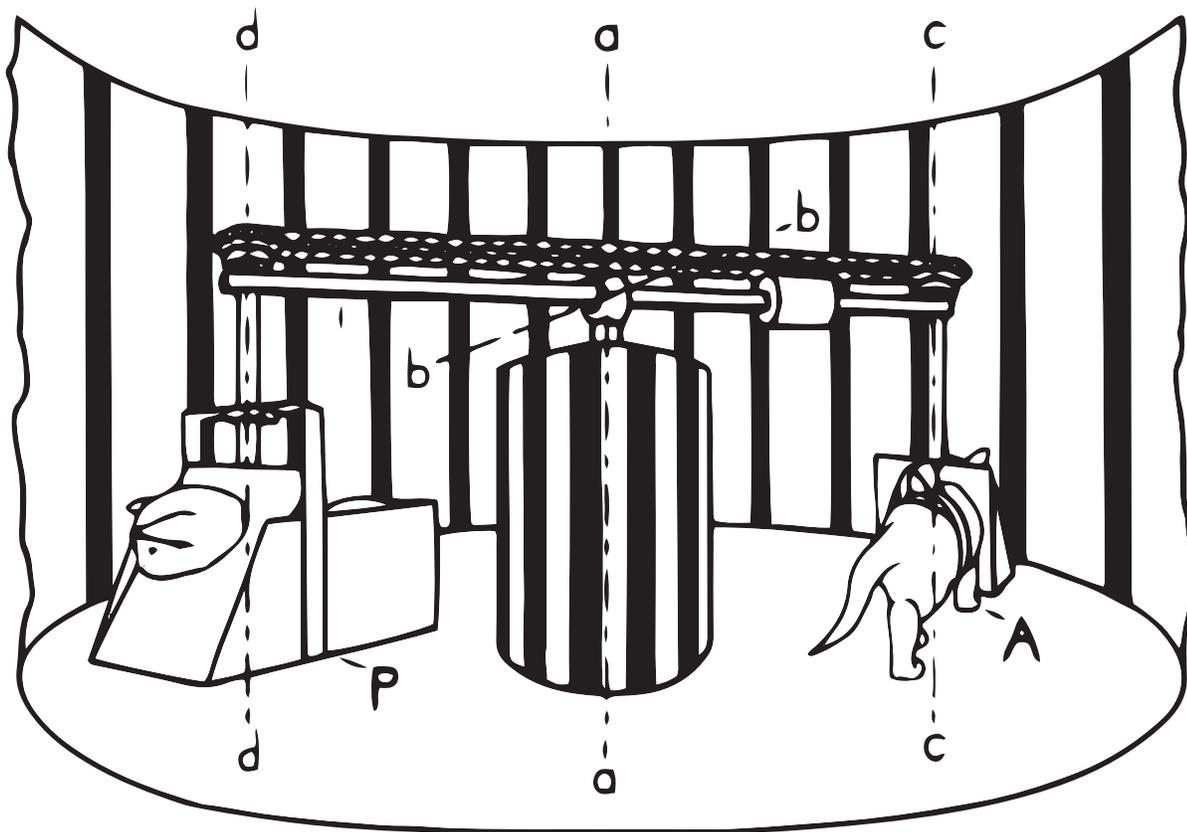


Figure 1. Apparatus used by Held and Hein. See text for explanation. (From Held & Hein, 1963, Fig. 1, p. 873. Used by permission.)

Learning paired associates by imagery. Research on verbal learning was once dominated by the paired associates task, which required learning arbitrary pairings of items. In the classical task, the paired items were nonsense syllables to rule out cognitive effects on learning, based on research by Ebbinghaus (Hoffman, Bringmann, Bamberg, & Klein, 1987, pp. 58-60). Eventually, however, researchers realized that meaning is the essence of verbal learning and they switched to arbitrarily paired real words presumed to be known by the participants. One of the great discoveries thereafter was that pairs of concrete nouns can be learned and remembered very easily by imagining an interaction between the referents of the nouns in each pair. This was actually a rediscovery of a principle that had been known in ancient Greece and thereafter (Yates, 1966). One 19th century writer gave a circular explanation: “Images are easily formed and never forgotten” (I am quoting from memory, having lost the reference).

Atkinson (1975) described a practical application that involved English-speakers’ learning a foreign-language vocabulary. The learner is instructed to encode each foreign word in the list as a concrete English noun that is acoustically related to the foreign word and then to imagine an interaction between the referents of the correct English word and the code word. One of his examples was learning that duck is pato in Spanish: Pato is pronounced roughly like “pahtoh,” so the acoustic code word could be pot and the interaction could be the image of a duck with a cooking pot on its head worn like a baseball cap. The research showed that using the imagery technique to

learn English-Spanish associations, for example, automatically yielded backward, Spanish-English associations, which had to be learned separately when rote memorization was used. The research also showed that the use of imagery improved long-term memory of the associations--a finding also obtained in research on learning pairs of English words (reviewed in Reese, 1977a, 1977b). Another finding--the one relevant here--is that Atkinson’s research showed that in general, the technique was more effective if the English words used as codes for the foreign words were provided by the researcher than if they were made up by the learner. In this sense, instruction worked better than entirely personal practice.

Learning language by use. The third case is about learning a language by using it. Using a language is interpreted to be direct experience, as implied in the subsection “Language Acquisition,” but it relies on examples and feedback provided by speakers of the language who are more experienced than the learner. In other words, it is a case of learning by doing as instructed (discussed in the section “Role of Indirect Experience”). A fictional example is in the 1985 movie with Mel Gibson and Tina Turner, “Mad Max Beyond Thunderdome.” Mad Max happened upon a community of children who spoke a primitive version of English. The children had survived a nuclear holocaust and afterwards they lived in a commune set up by adults who shortly abandoned them. The older children provided language models for the younger ones, but the older ones had been young children at the time of the isolation from adults, and therefore the language models they provided were developmentally retarded

in vocabulary and grammar. This outcome is consistent with an old saying, “A stream can’t rise above its source” (W. Smith, 1948, p. 625, cited an example of its use in 1700).

Two empirical examples illustrate the same point. First, language proficiency in slum adults and children tends to be deficient relative to middle-class language, presumably because children initially learn language from caregivers who are adults or older children. Second, standardized tests show that twins tend to have smaller measured vocabularies than nontwins, but other evidence indicates that the reason is that twins tend to develop their own words for some things and actions. Both examples presumably reflect group differences in the quality of the input and feedback.

In conclusion, learning language by using it involves a person’s own direct experience with the results of others’ direct experience, but the learner’s direct experience cannot produce a better effect than the others’ direct experience produced for them because the learner’s direct experience is indirect with respect to the others’ direct experience.

Learning methodology from scientific reports. In many graduate programs, students are required to read scientific reports published in journals rather than reading articles and books that are reviews of research findings. The rationale may be, in part, that reading the primary sources is a way to learn how to do research. If so, the effort is wasted, especially for learning how to do bench research. The general reason is that in science, research is conducted in a context of discovery and research results are reported in a context of justification (Reichenbach, 1938, pp. 6-7, 1947, p. 2, 1951, pp. 230-231). Annas said that Aristotle made the distinction in Posterior Analytics: Science begins with the simple and works upward, “not because that is how we discover truths, or even how we first learn them, but because that is the method of rational presentation that will best facilitate understanding of the subject-matter” (Annas, 1981, pp. 291-292). (I did not find this idea expressed so clearly in Posterior Analytics, and Annas gave no specific citation. However, chap. 13 in Book 1 of Posterior Analytics is relevant.)

Kaplan (1964, pp. 14-15) pointed out that different kinds of logic are used in the contexts of discovery and justification: “The ‘logic of discovery’ can be construed as a study of the reasons for entertaining a hypothesis, in contrast with the logic of proof, which deals with the reasons for accepting a hypothesis” (p. 17). Similarly, Vygotsky said, “The course of actual investigation never coincides with its final published record” (1934/1986, p. 209). More fully, Karl Marx said:

Of course, the method of presentation must differ in form from that of inquiry. The latter has to appropriate the material in detail, to analyse its different forms of development, to trace out their inner connection. Only after this work is done, can the actual movement be adequately described. If this is done successfully, if the life of the subject-matter is ideally reflected as in a mirror, then it may appear as if we have before us a mere a priori construction. (from the preface to the second edition of Capital; e.g., 1890/1906, pp. 24-25)

and

The concrete is concrete because it is the concentration of many determinations, hence unity of the diverse. It appears in the process of thinking, therefore, as a process of concentration, as a result, not as a point of departure, even though it is the point of departure in reality and hence also the point of departure for observation (Anschauung) and conception. Along the first path the full conception was evaporated to yield an abstract determination; along the second, the abstract determinations lead towards a reproduction of the concrete by way of thought. . . . [T]he method of rising from the abstract to the concrete is only the way in which thought appropriates the concrete, reproduces it as the concrete in the mind. (Marx, 1939/1973, p. 101)

Similarly, Pepper said he developed his “root-metaphor” theory of world views by examining the origins and features of world views, but in his 1942 book he presented the theory (chap. 4-5) before describing the world views (chap. 7-11). He said he used this sequence “to serve the purposes of exposition” (Pepper, 1942, p. 84) and “for reasons of simplicity of exposition” (Pepper, 1943, p. 603). A final example is that Flavell, Green, and Flavell (1986) called such a method “customary in scientific writing” (p. 4): In reporting the results of several related experiments, effective writers put the experiments in a sequence that best compels the conclusions, not necessarily the sequence in which the experiments were done.

Medawar (1963) and others (e.g., Goodstein, 2002; Madigan, Johnson, & Linton, 1995; Woodward & Goodstein, 1996) believed that the differences between reports of research and actual research is unfortunate because the reports mislead students and others who are not already skilled researchers. For example, it represents research as more organized and logical than it usually is in practice. This problem is especially acute when bench research methods are used. One characteristic of bench research is that in light of the incoming data, the researcher can change the procedures being used and even the research questions being asked. Another characteristic is that the data are recorded as notes in record books, and the notes cover not only observations but also minutiae regarding changes in the questions and procedures. The report of bench research is based on the notes but mercifully does not usually include all their contents, thus leaving uninitiated readers still uninitiated.

Brill and Yarden (2003) obtained evidence apparently contradicting Medawar and the others in a study of question-asking by high-school biology majors. The quality of the students’ questions was better in an experimental group than in a control group, and improved in the experimental group but not in the control group. However, the study was flawed in one way and irrelevant in one way. The flaw was that the topics of the experimental and control classes were different; the point leading to irrelevancy was that the research reports used in the experimental classes had been revised to make them more informative than the original reports. Specifically, students in the experimental classes, on developmental biology, learned by reading research reports that had been revised by adding information about the background of the research questions, simplifying the research methods and the discussion, omitting results not directly relevant to the research questions, and adding a section

on the contribution to knowledge. Students in a control class, on genetics, learned by reading a textbook.

PROBLEMS WITH SECOND-HAND EXPERIENCE

A problem that has often been discussed, and is implied by comments in the preceding subsection, is that second-hand experience is often too incomplete to be useful. An example is in an anonymous review of the first edition of Samuel Butler's *Evolution, Old & New*. Butler was a novelist and an amateur evolutionist, and in the book he challenged Charles Darwin's theory of natural selection and favored theories of inheritance of acquired characteristics, especially Buffon's, Erasmus Darwin's, and Lamarck's. The reviewer said, "One would think that Mr. Butler was the travelled and laborious observer of Nature, and Mr. Darwin the pert speculator, who takes all his facts at secondhand" (quoted in Butler, 1924, p. 343).

The problems of using secondary sources are magnified when they are based on writing a review of the published literature--or, worse, reading such a review, especially if the review involves meta-analysis (Reese, 1999). The reason is that a review--and especially a meta-analysis--is not only inevitably incomplete with respect to the details of direct experience but also likely to be expressed in abstract language. If it is, it is a kind of "etic" description (described in the section "A Language Explanation"). For example, Allik and Valsiner (1980) disparaged authors who merely talk about a phenomenon rather than investigate it directly. Writers who disparage talk-the-talk and praise walk-the-walk are making the same point. An example is a comment by Koffka (1925) about a theoretical description that Lindworsky (1919) had given of the behavior of animals in the transposition task. Koffka said, "Certainly it does not agree with the description Kohler gives of learning in hens" (note 208, p. 369). The implication is that Lindworsky was too far removed from the actual observations to understand the behavior of the animals. A remark by Vygotsky (1929/1981, p. 213) about Köhler's work is relevant and supports Koffka's argument. According to Vygotsky, Köhler observed that the chickens "sometimes fell stupefied to the ground and were completely upset when they were confronted with new shades of gray" (i.e., when they were confronted with transposition-test stimuli).

A literary example is Mayne Reid's inveighing against "closet-naturalists" (quoted from James, 1898/1978, p. 132; Skrupskelis, 1978, p. 220). Skrupskelis (p. 220) quoted an example: "There is one thing that is almost intolerable and that is the conceit of the 'closet naturalist,' who sneers at every thing as untrue that seems to show the least design on the part of the brute creation." The implication, I think, is that the design will be clear to anyone who actually experiences nature.

Another literary example may be remarks by "Jim Venture, Outdoorsman" in television and cartoon advertisements for Eveready batteries in the 1950s and 1960s. For example, a fishing or hunting party led by Venture would be awakened during the night by animal noises and Venture would shine his flashlight and reveal an untoward event such as a beaver chewing a canoe paddle or an animal raiding the food supplies. He would then say "A little tip from Jim Venture" and continue with something like "always store the paddles in a tree because beavers chew on them for the salt," or "always hang your food from a

limb to keep it away from the animals." The point here is that his good advice always came too late, after the untoward event had occurred. Perhaps the writers of the episodes were using a dramatic device based on belief that few persons would be as interested in an episode in which Venture gave the advice beforehand while smugly putting the canoe paddles in a tree, thus losing the drama of being awakened by chewing sounds and the opportunity to use a flashlight powered by Eveready batteries. Or perhaps they were applying the learning-by-doing principle to the fictional participants in the episode. (Or perhaps I have distorted the whole matter; my comments and quotations are based solely on my memory because I have not found any references to this advertising campaign in any literature.)

WHY IS LEARNING BY DOING EFFECTIVE?

In the present section, I discuss three kinds of explanation of why learning by doing is more effective than other methods. The first kind seems to me the most plausible, but all three are speculative. All three are based on assuming that the effectiveness of learning by doing reflects the ease or speed of learning, the relevance of what is learned, or the memorability of what is learned, or combinations of these virtues.

■ SELF-SHAPING

Perhaps learning by doing has the virtues it has because it is learning by self-shaping. Self-shaping would optimize the steps and their sequence because the effectiveness of the contingencies would be suited specifically to the doer by the doer, and the contingencies would therefore more effectively devise and sequence the steps in the learning process.

This explanation has some conceptual support: Peláez and Moreno (1998) suggested that a person who uses a rule that had been provided by others "may have no understanding of how to arrive at, or devise such a rule, because he or she may 'know that' but not 'know how or why' the contingencies specified in such rules are related. Rules taught by others are often learned via imitation processes" (pp. 206-207). Peláez and Moreno did not state the converse principle, which is that a self-generated rule is based on direct experience and therefore it leads to not only "knowing that" but also "knowing how or why" and therefore knowing whether and when to generalize the rule. That is, learning by imitation is inferior to learning by direct experience, such as learning by trial and error.

Contrary to the foregoing conclusion, Elizabeth Pennisi--a science writer for *Science*--commented that a study by Rendell and nine collaborators (2010) showed that the best way to adjust to a completely strange and inconstant environment is by imitating others rather than learning by trial and error (Pennisi, 2010). Rendell et al. found that emphasis on imitation was more effective than emphasis on trial and error, in that this strategy turned out to be the winner in a simulation game they devised. A problem with this finding is that the game was unrealistic in all but two ways. The conditions included a set of 100 fictitious actions and a population of 100 fictitious doers called "agents." Each action was identified by an index number but was not defined or given a meaningful label, and each was assigned

an abstract effectiveness value that varied at random across rounds of the procedure. Each agent initially had no actions in its repertoire but had one randomly assigned strategy that was unalterable throughout the agent's life. A strategy consisted of one or more of three "moves," called "innovate," "observe," and "exploit." Innovate was a trial-and-error method of acquiring an action and learning its effectiveness. It meant finding out the assigned effectiveness of one of the possible 100 actions, but the computer rather than the innovator selected the action to be assessed and the selection was random. Observe meant acquiring an action and learning its effectiveness by observing another agent's action, but neither the agent nor the action to be observed was selected by the observer. Rather, the computer randomly selected the action to be observed from those that had been Exploited in the preceding round. The observer received information about the randomly selected action and its effectiveness, but at random the information could be accurate or inaccurate. The part about possible inaccuracy is one of the realistic parts of the simulation. It means that an observer can misperceive a demonstrated action and misconstrue its effectiveness. The other realistic part was that Exploit meant performing an action the exploiter selected from its own repertoire.

Each round in the game consisted of one move by each agent, and the move made was determined by the strategy that had been assigned to the agent. The set of strategies was selected from computer programs submitted in a tournament with a 10,000 euro prize awarded for the program that yielded the largest lifetime effectiveness. An implication is that each of the 100 agents used an assigned, highly complex computer program and could not modify it in the face of nonoptimal feedback. In short, the results of the simulation study might be highly interesting to people who like game theories, but not to anyone interested in real-life problem solving.

■ THE MARXIST VIEW

Psychologists in the Soviet Union (Leontyev, 1981, pp. 134-135; Talyzina, 1975/1981, p. 38) gave a theoretical basis for the primacy of learning by doing: Learning is a reflection directly of the world, not directly of others' consciousnesses, and reflection is an act. Therefore, learning is accomplished by direct acting in and on the world. Consistently with a basic Marxist principle, the relation of learning to doing is mediated by social relations in that other persons provide conditions that encourage (mediate) learning by doing (the principle is Marx's 7th thesis on Feuerbach, identified in the subsection "Marxist version"). The provided conditions can be verbal, as in instructions and other verbal communications (Talyzina, 1975/1981, e.g., pp. 36-42), or they can be nonverbal, as in a Montessori school (Montessori, 1912/1964), or they can be both, as in Balanchine's school (Taper, 1960).

Another version of social mediation is group problem-solving, or group learning. For example, Amigues (1988) found that verbal exchanges between high school sophomores who were working in pairs facilitated problem solving, relative to the performance of students working alone. This kind of finding, for French children, has also been obtained with Japanese and

United States samples (Japan: Kobayashi, 1994; U.S.: e.g., Manion & Alexander, 1997; Yager, Johnson, & Johnson, 1985).

Another version is college work-study programs conceptualized as providing work experience in students' areas of interest. However, the practice apparently often deviates from the concept. My impression is that in United States colleges, a professor's work-study students not only provide free labor but also are likely to be scut workers who, for example, score research data or course-work tests and tabulate the scores without learning anything else about the research or course. This procedure is unfortunate in that it is contrary to the intention of work-study programs, but it is admirable for the professor's purposes in that it tends to make the work-study students blind about the research or course and therefore unbiased in the scoring and tabulating.

Work-study programs were also used extensively in China in the Mao Zedong era, "in line with Mao's desire to merge the practical with the theoretical, link labor with learning, make everyone work-conscious for nation-building, reduce differences between intellectual and manual workers, and eliminate elitist superiority from those in responsible positions" (Parker, 1977, p. 14). One kind of program was intended to relate the practical and theoretical aspects of specialty areas. For example, middle-school students repaired motors to gain experience and knowledge about electronics, or they grew small crops on school grounds to learn about agricultural practice and theory; and pharmacy students produced drugs commercially in a small factory. Another kind of program involved work outside one's specialty area, and it was required of faculty as well as students. For example, the electrical engineering faculty spent part of the year as farm laborers. The ostensible goal of this program was ideological--to reduce differences between intellectuals and manual workers in order to eliminate feelings of elitism in the intellectuals. However, both kinds of work-study reflected learning by doing because Mao believed that "only through practice (learning by doing and by participating in productive and political activities, etc.) can man gain true knowledge" (Kuo, 1976, p. 81).

■ A LANGUAGE EXPLANATION

A possible explanation of the effectiveness of learning by doing in humans is that it reflects at least in part the value of concrete language. The distinction between "etic" and "emic" methods in cultural anthropology (Keith, 1984) is relevant. This distinction is analogous to the phonetic-phonemic distinction in linguistics, from which anthropologists borrowed the italicized suffixes. As implied by this origin, etic versus emic is a structure versus meaning distinction. Both methods are attempts to understand a culture or a group by interpreting observed behaviors and informants' reports. The etic method is based on book-learning in the form of preconceived concepts, theories, or interpretations, and therefore the descriptions it generates are very likely to be stated in abstract language. The emic method begins with no preconceptions (or as few as possible) about the meanings of behaviors and symbols that will be encountered; the descriptions generated are based on direct experience and therefore are likely to be stated in concrete language. The emic method

continues with repeatedly “working through” the descriptions to obtain attempted interpretations in a kind of practice-theory-practice dialectic, such that the sequential interpretations are ever-improving but likely to stay closer to the concrete level of the initial descriptions. Dewey (1920, pp. 159-160) implicitly endorsed the emic method in saying, “It is nominally agreed upon as a commonplace that definitions ought to spring from concrete and specific cases rather than be invented in the empty air and imposed upon particulars.” (For other discussions of the etic and emic methods, see Beall & Eckert, 1986; Fry, 1986; Fry & Keith, 1986, p. xxi.)

For the present purpose, the most important feature of the emic method is that it requires direct experience with the topic under investigation. Thus, Marano (1982), who gave an “essentially Marxist” (R. Smith, 1982, p. 404) explication of the etic/emic distinction, disvalued “second” and “more remote” levels of analysis (p. 389)--levels at which authors cite primary sources or even more remote sources without benefit of personal direct experience. Marano said that some anthropologists “have never seen a bush Indian in their lives” (p. 389).

The likelihood that etic descriptions are abstract and emic descriptions are concrete has an important implication about memorability. A vast amount of research on verbal memory demonstrates that abstract nouns are less memorable than concrete nouns, most plausibly because concrete nouns have higher imagery values (see the subsection “Learning paired associates by imagery”). The probable outcome is that etic descriptions are less memorable than emic descriptions, which would make book-learning and other kinds of instruction less effective than learning by direct experience and other kinds of learning by doing.

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