
Samuel Messick

*Educational Testing Service*

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Educational Testing Service

This chapter confronts the question of what role cognitive abilities play or ought to play in educational achievement testing, which raises the prior question of what educational achievement tests are or ought to be. I begin by considering the nature of educational achievement as a construct in an attempt to circumscribe what achievement tests ought to be rather than by examining extant achievement tests that may be variously off target. Similar consideration is accorded cognitive ability as a construct. This distinction between constructs and the imperfect, variously contaminated tests that are purported to measure them is a critical recurrent theme in these deliberations. Other questions to be briefly addressed concern the role of cognitive abilities in the processes of school learning and the role of schooling in the development of cognitive abilities.

STRUCTURES OF KNOWLEDGE AND ABILITY

Educational achievement refers to what an individual knows and can do in a specified subject area. At issue is not merely the amount of knowledge accumulated but its organization or structure as a functional system for productive

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This chapter is dedicated to the memory of Robert L. Ebel. His enduring commitment to the improvement of educational measurement as a means of improving education is a worthy legacy for the field.
thinking, problem solving, and creative invention in the subject area as well as for further learning. The individual’s structure of knowledge is a critical aspect of educational achievement because it facilitates or hinders what he or she can do in the subject area. What a person can do in an area includes a variety of area-specific skills, such as extracting a square root or parsing a sentence or balancing a chemical equation, but also broader cognitive abilities that cut across subject areas, such as comprehension, memory retention and retrieval, reasoning, analysis and restructuring, evaluation or judgment, and fluency.

These broader cognitive abilities contribute to the assembly and structuring of knowledge, to the continual reassembly and restructuring of cumulating knowledge, to the accessing and retrieval of knowledge, and to its use in problem representation and solution. “Thus achievement,” in Snow’s (1980a) words, “is as much an organization function as it is an acquisition function. And new achievement depends as much on transfer of such organization as it does on transfer of specific prior facts and skills [p. 43].” Because cognitive abilities play a central role in both the acquisition and organization functions of educational achievement, their influence can hardly be suppressed or ignored in educational achievement testing that assesses knowledge structures. However, their role may be reduced in low-level achievement testing that stresses amount of information alone. Let us next consider the nature of developed knowledge structures in more detail and then the nature of developed abilities, before attempting to relate this formulation to other conceptions of educational achievement.

Knowledge Structure as Relational Understanding

A person’s structure of knowledge in a subject area includes not only declarative knowledge about substance (or information about *what*) but also procedural knowledge about methods (or information about *how*) and strategic knowledge about alternatives for goal setting and planning (or information about *which, when, and possibly why*). Although the acquisition of declarative and procedural knowledge is an explicit goal of typical instruction in most subject areas, strategic knowledge is rarely so and must often be acquired by induction, if at all (Greeno, 1980). Despite enormous variability in the effort, the principles and generalizations and first-order relations among concepts that provide coherent though rudimentary structure to newly acquired knowledge are also often taught explicitly. Possible exceptions are likely to occur at the beginning or elementary levels of learning in a field, where emphasis may be placed on the accumulation of a critical mass of information prior to organizing it. But the more idiosyncratic structures that relate newly acquired knowledge to existent knowledge structures (which sometimes entails qualitative reorganizations) and the more complex structures that evolve as expertise develops (which frequently entails qualitative reorganizations) are rarely under instructional control.
Knowledge structure basically refers to the structure of relationships among concepts. But as knowledge develops, these structures quickly go beyond classifications of concepts as well as first-order relations among concepts and classes to include organized systems of relationships, or schemas. As organizations of present knowledge, these schemas provide a context for the comprehension and interpretation of objects and events; hence, they profoundly influence the acquisition of new knowledge. Schemas guide the storage and retrieval of knowledge, the generalization and interpretation of ideas, and the initiation and regulation of action (Anderson, Spiro, & Montague, 1977). Thus, educational achievement is not just data driven by the bottom-up processing of incoming information but also conceptually driven by top-down assimilation to mental schemas or relational structures. Furthermore, as expertise develops, these schemas or relational systems themselves become organized in complex patterns, hierarchies, and dynamic networks. These networks are called dynamic because the knowledge structures of experts permit and even facilitate flexible reorganizations for the application of multiple perspectives to problem representation and solution. I have more to discuss later about the implications for educational achievement testing of the differences between novices and experts and between beginning learners and experienced learners in a field.

In the context of school learning, the development of students’ knowledge structures may be viewed as an explicit educational objective in its own right. In this connection, Scriven (1974) points out that knowledge structures comprise “organized relational knowledge,” which is what we ordinarily mean by understanding, and that implicit in the use of this latter term are a number of affective educational goals bearing on the development of attitudes, values, sensitivity, and appreciation. As Scriven (1974) put it, “there are deep reasons from cognitive psychology why understanding almost has to have an affective component, reasons which emerge in the verstehen theory of the philosophy of history, in the notion of empathy, and in concepts of modelling and role playing [p. 334].” Furthermore, affect and personality are intrinsically implicated in knowledge structure as a consequence of the individual’s psychology of knowledge (Tomkins, 1965); that is, what people know and are interested in knowing is a function of the kinds of persons they are and especially of their ideologies. Moreover, the degree of differentiation and hierarchic integration of the knowledge structure, the permeability of its boundaries, and the flexibility or rigidity of its dimensions or compartments are reflective of the individual’s personality and cognitive style (Messick, 1976, in press).

This view of educational achievement stresses the assessment of developed knowledge structure because it is both a product of earlier learning and at the same time is instrumental to, or a vehicle for, subsequent learning. Thus, knowledge structure is central whether the aim of achievement testing is the certification of past accomplishment, the diagnosis of present functioning, or the forecasting of future attainment. By emphasizing the role of knowledge structure as
the representation each learner constructs of a subject area to comprehend tasks and events, make sense of new experiences, and plan appropriate actions, this view is inherently constructivist in character. It is consistent with a variety of constructivist psychologies but does not derive from any one of them. For example, this view of learning and achievement is closely allied to what Bruner has called “instrumental conceptualism” (Bruner, Olver, & Greenfield, 1966). It is also quite congenial with Piaget’s overall stance on developmental process without committing to his position on developmental stages; that is, learning and the development of cognitive structure are seen as the active assimilation of experience to conceptual schemas, in balance with the restructuring of schemas in accommodation to reality-based or theoretically-correct structures.

Cognitive Abilities as Process Structures

Turning now to cognitive ability as a construct, let me stress at the outset that I am speaking of multiple abilities and not a unitary force or power, about developed abilities and not fixed abilities or capacities (Humphreys, 1962). Indeed, these abilities are clearly still developing well into adulthood (Cattell, 1971). They may develop more slowly later in learning than earlier and more rapidly for some individuals than others. Some may decline with advancing age, sometimes being compensated for by increasing facility in the utilization of other abilities. But, in general, cognitive abilities appear to respond over the long term to education and experience throughout the school years and beyond—even such broad intellective abilities as verbal comprehension and quantitative reasoning that are relatively well crystallized by adolescence (Cattell, 1971; Messick, 1980, 1982b).

Nor is there any implication of innateness of these cognitive abilities inherent either in the way they are measured or in the way they are theoretically conceptualized. At the level of measurement, the drawing of inferences about innate ability from an individual’s test performance has long been discredited. Such inferences drawn by early intelligence testers were based on two unsupportable assumptions about equality of motivation to learn and equality of opportunity to learn. These early testers reasoned that by selecting skills that all examinees have equal motivation and opportunity to acquire probably do not exist (Schwarz, 1971). Efforts to satisfy these assumptions continue, however, in the guise of so-called “culture-free” or “culture-fair” tests. Here, the usual ap-
approach is to select novel tasks where the opportunity (or rather, the lack of opportunity) for mastering them is more nearly equivalent in different cultural settings. This may better satisfy the opportunity assumption but at the expense of the motivation assumption, because tasks that are not emphasized in a culture depend for their salience or stimulus value on their intrinsic interest and the presumed importance of the testing to each examinee.

In contrast, the concept of developed abilities stresses the individual's current level of consistent proficiency however derived. Individual differences in developed abilities frankly reflect all sources of ability differences, including individual differences in prior motivation and opportunity to learn. Nonetheless, direct measures of the student's current functioning level, whatever its multiple determinants, are important in their own right for a variety of educational purposes. In much instructional planning, for example, it is critical to know what the student can do now. Some instructional strategies may differ, to be sure, depending on whether current ability levels are thought to reflect deficiencies or difficulties deriving from problems of motivation or of opportunity. In these instances, and perhaps as a general rule, measures of developed abilities should be interpreted in the context of independent information about motivation and opportunity, the latter being conceived broadly enough to include the quality of prior and current instruction (Heller, Holtzman, & Messick, 1982; Messick, 1983).

At the level of theory, most modern conceptions of ability development are basically interactionist in character; that is, they accord a causal role to interaction with the environment and hence are counter to earlier traditions of fixed intelligence and of genetically predetermined development (Hunt, 1961; Messick, 1972). Although many theorists hold that the primitive or rudimentary processes that initially interact with the environment are innate, these processes are not the abilities that develop out of the interaction. Even in those instances where a basic innate ability is postulated to start the interactive process, such as Cattell's (1971) fluid intelligence, this ability itself develops as a consequence of environmental interaction while it simultaneously facilitates the formation and development of specific abilities in response to differentiated environmental structure.

Many of these theories also stress a central role for positive transfer in learning and development. In the theory of ability development elaborated by Ferguson (1954, 1956), for example, abilities are viewed as learned proficiencies that attain relative stability through overlearning. They develop through repeated performance across similar tasks and gradually attain relative stability through exercise, challenge, and practice. Note that the reference is to relative stability, not fixity—that is, proficiency has developed to that part of the learning curve where additional effort yields small though nonzero increments. Learning that leads to the development of a particular ability, however, is influenced by prior learnings and previously established abilities through mechanisms of transfer. Indeed, one should expect that the most critical variables exerting transfer effects
on subsequent learning would be abilities—that is, those earlier acquisitions that have attained stability in performance.

The operative transfer function in this regard relates performance on a particular task, or set of similar tasks, both to training on those tasks and to proficiency levels on relevant abilities. If the learning period is sufficiently prolonged that significant changes in the abilities accumulate as a function of training and experience, those changes would also be taken into account. Ferguson (1954) maintains that "as the learning of a particular task continues, the ability to perform it becomes gradually differentiated from, although not necessarily independent of, other abilities which facilitate its differentiation [p. 110]." Because existing abilities, once developed, thus serve to facilitate the differentiation of other specific abilities, the operation of positive transfer produces positive correlations not only among tasks but among abilities. Thus, positive transfer furnishes a simple rationale for the emergence of broader and broader higher-order abilities organizing the primary abilities. This suggests that individuals not only develop multiple abilities but organized ability structures as well. It also suggests that major gains in intellectual power may not come so much from the further honing of already well-developed specific abilities as from their organization into more general and widely applicable assemblies of integrated ability complexes.

Furthermore, an important implication of Ferguson’s (1954, 1956) line of argument is that consistent differential exposure to various task domains leads to differential learning and hence to the emergence of different ability patterns in different learning environments or different cultures (Irvine, 1969; Lesser, Fifer, & Clark, 1965; Stodolsky & Lesser, 1967). One might expect, however, that higher-order abilities, if they indeed reflect general transfer components underlying the mutual facilitation of several primary abilities, would tend to apply across a variety of task requirements. Hence, higher-order abilities should appear more similar from one cultural group to another than do the more specialized primary abilities (MacArthur, 1968; Vernon, 1969).

Given different learning histories and different learning styles, it seems likely that—although the same basic ability processes may be involved in many different tasks—they may be strategically used more or less frequently in different tasks by different persons. Ability processes may also be organized and deployed in different ways for performing the same task, with attendant variation in effectiveness. This has led some investigators, such as Simon (1976) and Snow (1980b), to emphasize the assembly and control functions of abilities and ability structures.

For Guilford as for Ferguson, transfer also plays a critical role in ability development. Guilford (1967) claims that "the brain is apparently predesigned to perform in five major ways [p. 417]" corresponding to the five information-processing operations of cognition or comprehension, memory, convergent production, divergent production, and evaluation that comprise the heart of his factorial model of the structure of intellect. Specific intellectual abilities develop
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through the repeated use of these five operations to process information in the individual’s environment, which Guilford’s extensive empirical investigations suggest is so structured as to contain 24 types of information generated by the cross-classification of four types of content (figural, symbolic, semantic, behavioral) and six types of form or product (units, classes, relations, systems, transformations, implications).

In Guilford’s (1967) view, these specific abilities are generalized skills or habits that develop through transfer effects occurring by virtue of similarities in the task-to-task activities of a particular operation–content–product type. How well any specific ability develops depends on how much and how effectively the individual exercises the requisite operation in relation to the particular content–product combination. This in turn depends on the opportunities the person’s environment offers to operate on such combinations and the individual’s needs to cope with those offerings. Because tasks within the same operation–content–product category are more similar in shared activities than those in different categories, a specific ability should eventually develop via transfer for every cell of the operation by content by product cross-classification. This would yield the 120 abilities in Guilford’s structure of intellect. Moreover, because similarities in shared activities may cut across content–product differences for a given operation such as memory or across operation–product differences for a given content such as figural, higher-order abilities such as general memory facility or general figural facility may also emerge (Guilford, 1981; Messick, 1973).

Cattell’s (1971) theory of ability development is especially pertinent to issues of educational achievement because he explicitly stresses not only the role of transfer processes in development but the transfer power of developed abilities in task performance. Originating in the investment of innate fluid intelligence in the learning of particular tasks or task domains, specific task skills become integrated into primary abilities that cut across similar or related tasks. That is, because of an inherent similarity in the required activities in a particular domain, a unity of functioning develops—or in Cattell’s (1971) words, “a coherent set of habit skills, knowledge, conceptual developments, and tactical and strategic ‘know how’ [p. 319].” These primary abilities, which Cattell calls “agencies,” become organized through their mutually facilitative transfer effects and shared investments of fluid intelligence into higher-order abilities.

Cattell (1971) gives major emphasis to those primary abilities derived from the learning of judgmental skills associated with the more abstract parts of school curricula and nonschool experiences, such as verbal ability and numerical ability. In the course of education and experience, these judgmental skills become organized into a broad higher-order ability complex, which Cattell calls crystallized intelligence. Other higher-order abilities include general memory, general visualization, and general retrieval or fluency. In underscoring the increasing transfer power of primary abilities and higher-order abilities, Cattell (1971) likens a specific transferable skill to a “tool,” by which he means “some insightful
device in thinking and acting which, once picked up, enables the user to handle a whole group of further performances [p. 316]." He conceives of an agency or primary ability as a "whole toolbox of cognitively consistent habits [p. 321]," which would make crystallized intelligence a veritable workshop of transferable structures of ability processes. For Cattell, crystallized intelligence comprises highly general abstractions that possess wider transfer effects than those of any of the agencies and hence displays a broad generality of useful application.

From Cattell’s (1971) description of abilities as organized complexes of transferable concepts and skills and from Guilford’s (1967) formulation of abilities in terms of information-processing operations, it seems clear that abilities in this factor-analytic tradition may be conceptualized as process structures, to use Carroll’s (1974) term, or as stable constellations of psychological processes. This usage is consistent with information-processing formulations in cognitive psychology, as exemplified by Snow’s (1980b) conception of abilities as structures of assembly and control processes as well as performance processes and by Sternberg’s (1977) treatment of intellectual abilities in terms of both structure and process. On the one hand, Sternberg characterizes abilities as task proficiencies—specifically, as particular constellations of information-processing components that satisfy the requirements of a given task or type of task. On the other hand, he also views abilities as dimensions of individual differences—specifically, as generalized constellations of information-processing components that form stable patterns of individual differences across multiple tasks or types of tasks.

The critical concept bridging these two notions is that abilities are stable consistencies within individuals (across variations in setting, time, and task) that reliably differentiate among individuals (Messick, 1982a). The intraindividual pattern of abilities for a particular student is the ability structure of concern in educational achievement. This may or may not include all the ability dimensions, or interrelate them in the same way, as in interindividual structures of between-person differences. Nevertheless, research on the structure of individual differences does provide many of the dimensions and associated ability measures for characterizing and assessing individual structures (Burt, 1949; Cattell, 1971; Ekstrom, French, & Harman, 1976, 1979; Guilford, 1967; Hakstian & Cattell, 1974).

Moreover, because abilities in this view are constellations of information-processing components operative either in a particular task or stably across multiple tasks, they in turn may serve as components or organizers of still more complex or temporally extended sequential processes, such as problem solving or creative production (Guilford, 1967; Messick, 1972, 1973). Thus, functioning much like subroutines or prior assemblies in computer terms, abilities not only facilitate performance on specific tasks and enhance the learning of new tasks but may also serve as operational modules in higher-order psychological processes. Overall, then, a person’s developed ability structure is conceptualized here as a

In educational achievement, abilities and ability structure are engaged with knowledge structure in the performance of subject-area tasks. Abilities and knowledge combine in ways guided by and consistent with knowledge structure to form patterned complexes that may differ by subject area, so that problem solving in physics, for example, appears different from problem solving in biology or in political science. Furthermore, as expertise develops these ability–knowledge complexes may become markedly, even qualitatively, different by area. Thus, abilities are not revealed directly in educational achievement testing but rather are entailed in ability–knowledge combinations. Yet they do operate in achievement conjointly with knowledge, and hence ability tests and achievement tests will overlap considerably and correlate substantially—except possibly, as indicated earlier, in low-level achievement testing that primarily stresses information retrieval and first-order relations. Moreover, because the engagement of abilities is extensive and complex in high-level achievement, it would not be surprising to find quite high correlations at advanced achievement levels. For example, in a Graduate Record Examinations rescaling study, when 19 advanced subject-matter tests were correlated with a combination of verbal and quantitative abilities, six coefficients were between .71 and .81, whereas nine were between .60 and .70 (Wallmark, 1969).

Still, cognitive abilities are not the same as subject-matter achievement, even those representing generalized school-related learnings such as crystallized intelligence. Indeed, for many educational purposes it is important to assess them separately. That is, a person may fail in subject-area task performance because of inadequate knowledge (especially strategic knowledge), dysfunctional knowledge structure, ineffective mobilization or organization of a complex of relevant abilities, or deficiencies in any one of these abilities. Achievement tests tap all of these in concert and although they may often effectively separate knowledge retrieval from knowledge use, they do not provide independent assessments of cognitive abilities. Thus, the coordinate measurement of cognitive abilities as well as subject-matter achievement may contribute to the comprehensive diagnosis of academic difficulties.

Cognitive abilities are independent of subject matter but they are by no means content-free; rather, they cut across content areas. In some instances, they may be specialized by type of content such as verbal, numerical, or figural, but at higher orders they represent more general functions such as memory or fluency. The route taken to arrive at this point may have appeared to be circuitous, but it was a deliberate attempt to forge an explicit link between concern over the role of cognitive abilities in achievement testing and 50 years of factor-analytic work on the delineation and measurement of abilities.
Contrasting Views of Knowledge Versus Ability in Achievement Testing

This view of educational achievement as a compound of developed ability and knowledge structures shares some important features with other conceptions of achievement but also entails some critical differences in substance and emphasis. As an instance, Ebel (1969, this volume) maintains that “the essence of achievement is command of useful verbal knowledge [1969, p. 66].” Ebel (1974, 1982) makes it clear that he is speaking not merely about amount of knowledge or information but about knowledge structure—that is, about the “structure of relationships among concepts, a structure built out of information by processes of thought [1974, p. 317].” But he limits this structure specifically to verbal knowledge, whereas the present formulation admits any form of knowledge, whether verbal or visuospatial or whatever. Ebel (1969, 1982) also stresses the usefulness of the knowledge, with the implication that useful knowledge is what gets built into the knowledge structure whereas useless knowledge is soon forgotten. In contrast, the present formulation stresses the usefulness of the knowledge structure as a functional system in thinking. However, the critical difference between Ebel’s view and the present one is his explicit exclusion of general cognitive abilities except for knowledge-dependent, area-specific skills such as adding fractions or formulating sentences (Ebel, 1969, 1974). This is puzzling in light of Ebel’s insistence that achievement is the command of knowledge because, as Snow (1980a) has underscored, “‘command’ implies organization, generalization, facile adaptation and application of knowledge in new contexts; that is what, I contend, general mental abilities are! [p. 43].”

In contrast to Ebel’s exclusion of developed cognitive abilities from achievement, Anastasi (1976, 1980, this volume) subsumes achievement under the rubric of developed abilities. She refers to a continuum of tests of developed abilities that vary in their degree of experiential specificity. Included along with “culture-fair” tests, tests of verbal and nonverbal intelligence, and tests of differentiated cognitive abilities are course-oriented achievement tests of technical skills and factual knowledge as well as broadly oriented achievement tests of major long-term educational goals such as the interpretation of literature or the understanding and application of scientific principles (Anastasi, 1976).

The differentiation among educational and psychological tests in terms of experiential specificity is a helpful one, and the implication that these tests “fuse imperceptibly” with one another is an important caveat against misuse. For example, some tests designed to assess subject-matter achievement so stress the application of learned skills to the solution of new problems in the area that they appear to measure general reasoning and other cognitive abilities fairly independent of factual content; whereas some other tests designed to assess general scholastic ability draw freely on varieties of specific word knowledge and arithmetic principles learned in school. However, the subtle implication that because
existing tests overlap markedly or are misaligned with their constructs, therefore the construct distinctions are unimportant—that "the terms intelligence, aptitudes, abilities, and achievements are indeed different words for essentially the same human characteristics [Ebel, 1980, p. 11]"—does not follow at all and is insidious in its impact on new measurement efforts. What is needed is not a downplaying and blurring of the construct distinctions but, rather, attempts to illuminate these distinctions in refined measures of knowledge structures, of cognitive abilities as process structures, and of ability–knowledge complexes in problem representation and solution.

EXPERTISE AND APTITUDE

It should be noted that the present conception of educational achievement is not tied to program or course objectives. Educational achievement in this view refers to what a person knows and can do in a subject area, not just the degree to which the person knows and can do what was taught. Such a narrowing of purview can of course be imposed and for some uses of achievement tests, such as the certification of curriculum mastery or the evaluation of program or course effectiveness, probably should be imposed. Even here, however, one should not automatically preclude the assessment of generalization and transfer in the former instance or of potential side effects in the latter. The point is that for other uses of achievement tests—such as the diagnosis of academic strengths and weaknesses as a basis for remediation or for adaptive instruction and the prediction of future attainment as a basis for selection, placement, or assignment to alternative treatments—the broader view may offer added value. Some examples of this added value come from a consideration of the differences between beginning and experienced learners in a field and between novices and experts.

Assessing What Is Learned, Not Only What Is Taught

As we have seen, when students learn something specific, they usually also learn something general; that is, they tend to educe general attributes from specific instances and evolve general structures for representing and understanding new specifics. For beginning students in a field, these rudimentary knowledge structures tend to be idiosyncratic, because new information is assimilated to the student’s intuitions about the subject derived from everyday experiences. These structures or informal theories are also frequently fragmented or overextended or misaligned with reality. In some instances, these informal theories are simply vague and poorly articulated versions of acceptable structures, requiring the progressive differentiation and reintegration of already existing ideas with new knowledge (Ausubel, 1968). In other instances, however, the student’s informal notions may be seriously at variance with formal theories or accepted structures,
in which case they constitute what Driver has called “alternative frameworks” (Driver, 1981, 1982; Driver & Easley, 1978). These alternative frameworks, being based on student’s intuitions, tend to be quite persistently embraced and are frequently resistant to change through instruction.

A number of common alternative frameworks have been uncovered in science education in particular. For example, some beginning biology students evince a persistent tendency to think in Lamarckian terms (Deadman & Kelly, 1978) and some believe, despite instruction on photosynthesis to the contrary, that plant “food” comes exclusively from the ground (Driver, 1982). Some beginning physics students have been found adhering to non-Newtonian ideas about motion and to notions of impetus reminiscent of pre-Galilean dynamics (Viennot, 1979). It appears that intuitions are not readily abandoned and, in particular, that scientific principles that are counter-intuitive are not easily assimilated. If conceptual learning entails such radical restructurings of ideas, it is not enough to assess for diagnostic purposes whether or not the student knows what was taught—one must also assess what else the student “knows” or believes about the subject.

A similar point holds for the assessment of expert-level achievement but for a different reason: namely, much of what is learned in the development of expertise, we do not know how to teach. However, from a convergence of recent studies we have begun to characterize, albeit tentatively, some of the complexities of developed knowledge and ability structures that constitute the power of expertise (Chi, Feltovich, & Glaser, 1981; Chiesi, Spilich, & Voss, 1979; Glaser, 1981; Hunter, 1982; Larkin, McDermott, Simon, & Simon, 1980a, 1980b; Rigney, 1980; Simon, 1976). Hence, we may be able to approach the assessment of expertise in terms of these outcomes of learning and development, which are beginning to become clear, rather than in terms of the objectives of teaching, which in the case of expertise continue to be vague and ill-defined.

It appears from this recent work that not only do experts know more than novices or have a vastly richer store of relevant knowledge in long-term memory, they also structure and continually restructure knowledge in more complex ways. In particular, experts construct complex schemas that combine some of the dimensions and simpler schemas used by novices into integrated functional patterns, while at the same time discarding as redundant or irrelevant some other dimensions that novices attend to. Experts also develop new patterns of perceiving, thinking, and acting or what Ian Hunter (1982) calls “adroitly usable patterned complexes.” These complex abilities to perceive and apply both patterned relational schemas and the attendant action sequences strongly influence the nature of problem representations, the avoidance of irrelevancies, and the organization of performance and solution processes. Experts also develop greater speed and fluency of performance, implying in addition to the restructuring already mentioned a continual tuning of processes, the automatization of routines and control processes, and the shedding of redundant processes (Rumelhart & Norman, 1976). Furthermore, in contrast to novices, experts appear more capable of
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flexible restructuring for the application of multiple perspectives to problem representation and solution as well as for the adjustment or replacement of dysfunctional initial schemas as hypotheses change.

In addition to providing possible guidelines for the assessment of expertise, these findings suggest that not only do abilities facilitate the development of more complex abilities but so do rich and extensive knowledge structures. Thus, developed abilities influence the structuring and restructuring of knowledge whereas developed knowledge structures influence the organization and application of abilities, leading to increasingly more complex structures of each. Although the "adroitly usable patterned complexes" of ability developed by experts are inherently knowledge-dependent, some of their structural and functional aspects may be generalizable to the learning of other fields. For example, when an expert in one field attempts to learn a different subject matter, he or she may be more able than the ordinary novice to discern the deep structure of the new field, to ignore irrelevancies, and to perceive the patterned relationships entailed in constructing complex schemas, even though a massive store of knowledge in the field has not yet been acquired. If this is possible, then what we should mean by a generalist is not a jack-of-all trades and a master of none, but a jack-of-all-trades and a master of one or, preferably, two. Thus, expertise in one field may be aptitude for the functional mastery of another.

Aptitudes as Facilitators and Forecasters of Performance

This brings us to the construct of aptitude which, according to Snow (1980a), refers to "'psychological characteristics that predispose and thus predict differences in later learning under specified instructional conditions [p. 41].'” Again, at the outset I want to make clear that there is no necessary implication of innateness in this use of the term. This conception comprises two distinct but closely related notions of aptitude—namely, aptitude as a forecaster of learning or performance and aptitude as a facilitator of learning or performance (Cronbach & Snow, 1977). Although the applied emphasis may be on predictiveness per se, the scientific emphasis—in such psychoeducational research as the study of aptitude-treatment interactions—is mainly on illuminating the facilitating processes that underlie the prediction (Snow, 1980a). This may lead not only to better prediction but to better and more responsible use of the predictive findings. A compatible conception of aptitude as learning rate is also current (Carroll, 1963; Green, 1974), but again the primary concern is with the process structures that underlie differences in rate (Carroll, 1974).

Considerable confusion arises when aptitude tests as predictors are contrasted with achievement tests as measures, because achievement in a subject-matter area happens frequently to be quite predictive of subsequent performance in the same field. Subject-matter achievement is also often predictive of performance in
related fields, although somewhat less so, whereas measures of general ability complexes such as tests of scholastic ability or of crystallized intelligence tend to be more widely predictive across disparate fields. Furthermore, the distinction between developed abilities and developed knowledge structures cuts across this aptitude–achievement contrast, as does Anastasi’s (1976) continuum of experiential specificity and Snow’s (1980a) pyramid of referent generality. The latter, consistent with the present formulation, illustrates why ability and achievement constructs are more readily distinguishable both conceptually and empirically at more specific than more general levels.

Aptitudes may be specific or general and so may achievements, developed abilities, or knowledge structures. Developed abilities and knowledge structures, being evolved through education and experience, are both achievements, to be sure. Yet they are also predictive of subsequent learning and performance, more broadly in the case of abilities and in more focused fashion in the case of knowledge structures, thereby qualifying as aptitudes as well. But the predictive developed ability is not the same as the subsequent performance, nor is it a measure of that performance. Similarly, current achievement that predicts future achievement is not a measure of that later achievement.

This confusion between prediction and measurement has led some investigators to argue that aptitudes, abilities, and achievements are “essentially the same human characteristics [Ebel, 1980, p. 11]” and that aptitude, ability, and achievement tests are “fundamentally similar” in what they measure (Anastasi, 1980). The point may be well taken in regard to many existing tests. But as Carroll (1974) has pointed out, “with a definition of aptitude that identifies it with the present state of the individual as symptomatic of future performance, it is difficult to see why there should be any great difficulty in distinguishing between aptitude and achievement as concepts [p. 287].” Similarly, in spite of high correlations between tests of educational achievement and tests of developed cognitive abilities but in light of their differential responsiveness to direct instruction, their differential involvement in aptitude-treatment interactions, their different courses of development, and differences in their process and content components, it is difficult to see why there should be any great problem in distinguishing between educational achievement and cognitive abilities as constructs.

THE FAILINGS OF FALLACIES

We have been alerted to the jingle fallacy, whereby tests purported to measure the same construct are naively taken to measure the same thing, and, to the jangle fallacy, whereby tests purported to measure different constructs are naively taken to measure different things (Kelley, 1927). We now find that if tests purported to measure different constructs correlate highly with each other, the
constructs are taken to be the same thing. This might be called the *jingle–jangle* fallacy, because convergent correlational evidence, which would support jingles, is taken as tantamount to the absence of discriminant experimental evidence, which would support jangles. However, I prefer to call it the *jungle* fallacy because, by failing to maintain the distinction between constructs and their indicants or measures, we are in danger of reverting to the jungle of operationism whereby test meaning resides in each investigator’s measurement operations rather than in validated relational or nomological networks.

What is needed now is what has always been needed—namely, not just the empirical buttressing of constructs inferred from existing measures but the development and validation of measures attuned to constructs, especially as constructs evolve or change with conceptualizations of new evidence. In educational theory and practice today, we must recognize, to use Glaser’s (1980) words, that “the study of learning appears to be taking on the characteristics of a developmental psychology of performance changes—the study of changes that occur as different knowledge structures and complex cognitive strategies are acquired, and the study of conditions that affect these transitions in competence [p. 322].” Accordingly, in educational measurement today, we must recognize, to use Snow’s (1980a) words, that “achievement constructs refer to complex dynamic cognitive structures [p. 44].” Hence, to better serve both theory and practice, new approaches to achievement measurement should be more complex, dynamic, and cognitive.

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