Instructional Psychology: Past, Present, and Future

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Inleiding

Het hiernavolgende artikel is de bewerkte versie van een lezing die professor R. Glaser heeft gehouden te Leuven op 8 mei 1980, ter gelegenheid van het aan hem toegekende doctoraat honoris causa van de Katholieke Universiteit.

De redactie van Pedagogische Studiën heeft het nuttig geoordeeld dit artikel op te nemen, omdat het een representatieve weergave is van de Amerikaanse benadering van de onderwijspsychologie. Tevens geeft het een goed, zij het beknopt, overzicht van de huidige stand van zaken met betrekking tot de onderwijspsychologie in de U.S.A., geplaatst in een historisch perspectief. Mede door de uitvoerige verwijzingen naar relevante literatuur, die ook in het Nederlandse taalgebied relatief gemakkelijk bereikbaar is, biedt het artikel de geïnteresseerde lezer een overzichtelijke introductie tot de huidige 'information-processing approach' van onderwijsleerprocessen.

Het artikel is in het Engels opgenomen, omdat volgens de redactie een dergelijke inleiding door een erkende autoriteit op een bepaald gebied het beste in de oorspronkelijke taal kan geschieden.

Abstract

The history of instructional psychology is traced through Thorndike, Dewey, Skinner, and recent developments. At the present time, instructional psychology, with the methods and concepts of cognitive psychology, is focusing on the acquisition of competence. Researchers are examining cognitive processes required in advanced levels of reading and text comprehension; the computation and advanced problem-solving skills needed in mathematics; the skills of learning assessed by aptitude tests; and the effects of the interaction between initial ability and classroom processes on school achievement. The emerging field of instructional psychology can be described in terms of four major components: the initial state of the learner, the nature of the competence to be attained, the transition processes between these two stages, and ways of assessing and monitoring performance changes in the acquisition of competence. Principles that should guide the future development of a psychology of instruction are discussed.

1. *History and background*

Any profession relating to the human condition rests its practices on a foundation of beliefs about human nature. At one time, economists developed economic theory on the basis of a metaphorical model of the rational man; early psychoanalysts based their craft on Freud's description of human development. Educators also have espoused principles on which their educational practices are based. William James, G. Stanley Hall, Edward Thorndike, John Dewey, B. F. Skinner, and Jean Piaget all provided various theories of human behavior that have influenced education. In common agreement, these individuals pointed out that the scientific study of human behavior was fundamental to establishing a disciplinary base for educational practice. They would certainly also agree that an ethical philosophy is necessary for education, and that it is a necessary, but insufficient, condition. What is required is that both scientific knowledge and interpretations of human values and social objectives combine to yield an effective educational profession.

It is the scientific, psychological base that is the focus of this paper. In particular, it is the translation of scientific knowledge into practice and of practice into scientific questions. At the beginning of this century

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in America, Thorndike and Dewey, stimulated by the development of scientific psychology imported from the European laboratories, were encouraging active intercourse between science and its application to education (Dewey, 1900; Thorndike, 1922). Among the numerous conceptions that might have dominated psychological thought in this early period, association theory and functional psychology had great attraction because of their seemingly practical appeal. By their nature, these theories appeared to promise that changes could be brought about in the environment to influence the human condition and to lead to improvements in child care, mental health, and education.

Thorndike, heavily involved in laboratory work on the psychology of learning, applied association theory, the theory of S-R bonds, to the psychology of instruction in various subject matters and to educational experimentation on transfer of training and the doctrine of formal discipline. His research proceeded in a very direct fashion; he applied certain laws of learning – the laws of S-R bonds, the law of effect, and findings about the specificity of transfer – to the design of instruction and materials for teaching (Thorndike, 1923).

In contrast, Dewey resisted the prominent associationistic trend and differed not only with Thorndike's beliefs about the nature of human behavior, but also with his view of the relationship between psychology and its application. Dewey envisioned a 'linking science' that intervened between scientific theory and practical application, and that could provide a conceptual framework into which knowledge obtained from both scientific work and educational practice could interact, cumulate, and modify each other. In his own work, Dewey elected to leave aside the long-term venture of the translation of science into practice. He believed that it was most immediately important to move to implementation in laboratory schools, even though the underlying principles of human behavior were only very generally defined. In Dewey's thinking, the findings of science would eventually work their way into practical application, but the immediate development of schools needed to proceed on the basis of available, more intuitive principles.

Although Thorndike and Dewey differed in their theoretical and empirical approaches, they both were firmly convinced that the development of a science of human behavior was fundamental to the growth of the educational profession. Strong connections between these two fields were necessary for the mutual reinforcement of science and practice. However, following their time, these connections became weaker (Glaser, 1976).

1.1. *A loosening of ties*

The spirit of close affinity between psychology and education persisted for a short time after Dewey and Thorndike; but following this period, education and psychology went their separate ways. The distance between the two fields resulted from the divergent activities that preoccupied each of them. It may not be too much of an oversimplification of history to say that each field addressed the immediately demanding problem of building their own discipline, with little apparent need for relationships with one another.

Psychology, on the one hand, aspired to become a natural science and take its place among the 'hard' sciences. In order to accomplish this, psychologists went into the laboratory to work out experimental techniques using tasks designed more for theoretical purposes than for relevance to realistic educational tasks. Education, on the other hand, particularly educational psychology and the psychometrics of educational testing, found their challenges primarily with practitioners and with the practical problems of teacher training, teaching methods, curriculum development, and testing for the schools. As psychologists became concerned with building their field, so too did educators become concerned with building the educational profession, and less effort was devoted to nurturing its scientific and disciplinary roots.

As psychology and education set about these urgent and different tasks, psychologists and psychology departments were established in faculties of arts and sciences, and most educational psychologists joined faculties of education. The two enterprises, the main body of experimental psychology and educational psychology, took on different characteristics because of the climate in which they worked and their constituencies. During this period of mutual insularity – lasting up to World War II (with some exception during World War I) when experts from both fields worked on problems of training – educational psychologists abstracted instructional principles from existing learning theory and tested these principles in classroom experiments and case studies that were presented to teachers as illustrations of general guiding principles that could influence their practices. Experimental and theoretical psychologists had little involvement in the development of instructional practices and materials. Also of little concern was the study of those problems in learning and performance that arose in classrooms - problems that could influence psychological theory and laboratory experimentation. In the 'pure' psychology departments of the faculties of arts and sciences, educational psychology and concerns with instruction were not prestigious activities.

The estrangement between psychology and education led to certain interesting paradoxes. The field of testing and psychometrics, strongly influenced by the needs of education and training in society, developed a strong technology, and theories of mental tests that were bolstered by factor analysis, but unsupported by an underlying psychological theory of learning and performance (Anastasi, 1976; Cronbach, 1957). Psychometrics was largely an engineering enterprise, and questions that arose in its application did not generally feed back into experimental psychology and related theory. Investigators studying learning, memory, problem solving, and thinking carried out their work as a theoretical and descriptive enterprise, and showed little inclination for the development of a framework for application. Theoretical problems and results that could have been generated by application were generally unavailable to challenge theories and findings from the laboratory.

1.2. *Rapprochement*

Following World War II and during the 1950's, there were two major starts toward rapprochement between psychology and instructional technology. The first was a large research effort sponsored by the military on problems of training. Many psychologists, both those recognized at the time and those who were to become well known later, became involved in the effort. In both the United States and Europe, they brought various points of view and methodologies, including techniques for the analyses of skilled performance, to the investigation of instruction (Glaser, 1964, 1965a; Melton, 1957; Skinner, 1965). The war led to a vast increase in research on human skills and competence, work referred to as 'human engineering' or 'human factors' research. Much of this work was concerned with the kind of human performance involved when individuals controlled complex man-machine systems (Broadbent, 1973), and comparisons and analogies were made between human processes and the mechanisms of mechanical and electronic systems such as servomechanisms and computers. A link was forged between research in human cognitive capacities and models of these performance capabilities in terms of the hardware with which they interacted. This significantly contributed to the present-day modeling of human performance in terms of computer information-processing systems (Newell & Simon, 1972).

The partnership of psychology and education was also rejuvenated by the movement of Skinner's operant psychology into the educational scene (Glaser, 1978). In the late 1950's and 1960's, teaching machines and programmed instruction had a tremendous surge of interest which has been well documented (Glaser, 1965b; Lumsdaine & Glaser, 1960). Unfortunately, the programming of instruction was widely misunderstood. The first programs emerging from an experimental analysis of behavior were copied only in certain superficial aspects (Skinner, 1965). New applications were too quickly separated from the theory underlying them. The necessary contact between theory and practice through appropriate linkages was not maintained. Thus, a mutually correcting system, in which failures and limitations in both application and theory could be understood, modified, and improved, was neglected.

These attempts to integrate education and psychology were encouraged by the social and scientific Zeitgeist of the 1960's. Society urged improvements in the educational system, educators asked for research and development, and many psychologists found educational applications, remote or immediate, a reasonable test of their work. A new field of instructional psychology was taking shape. In 1964, a yearbook on *Theories of Learning and Instruction* appeared that included chapters by many prominent psychologists (Hilgard, 1964). In this book, Bruner discussed the nature of a theory of instruction and made a distinction between descriptive theories of learning and prescriptive theories of instruction.

The developing instructional psychology began to realize Dewey's linking science, relying upon the interaction between theoretical and experimental analysis and applied problems. In 1966, the respected classic textbook by Hilgard on *Theories of Learning* (first published in 1948) included in its third edition a chapter on 'Learning and the Technology of Instruction' (Hilgard & Bower, 1966). In the later 1975 edition, the chapter was called 'Theory if Instruction' and included, among other things, Gagné's hierarchical theory (Gagné, 1962, 1970), Bruner's cognitive-developmental theory (Bruner, 1964, 1966), Atkinson's decision-theoretical analysis for optimizing learning (Atkinson, 1972, 1974; Atkinson & Paulson, 1972), Carroll's model of school learning (Carroll, 1962, 1963), and Skinner's programmed learning (Glaser, 1978). The first review entitled 'Instructional Psychology' (Gagné & Rohwer, 1969) appeared in the 1969 *Annual Review of Psychology*. Subsequent annual reviews of this field have also appeared (Glaser & Resnick, 1972; Lumsdaine & Wittrock, 1977; McKeachie, 1974; Resnick, in press).

At the present time, cognitive psychology is the dominant theoretical force in instructional psychology and, indeed, in modern psychological science. However, much present application relies upon the behavioristic approaches of the past, and pervades many settings where the learning and relearning of behavior are a significant phenomenon; particularly therapeutic situations, institutional environments, special education, and instructional settings at all levels of education (Kazdin, 1975). The work in behavior modification has led oftentimes to impressive accomplishments, particularly in circumscribed situations, and with the relatively specifiable and less complex aspects of human behavior. In addition, the results obtained are providing evidence for assessing the adequacies and inadequacies of the underlying scientific base. Certain limitations of these applications are beginning to emerge that are shown in their long-range generalizable effects and in their relevance to the complex behavior involved in thinking and problem solving, acquiring understanding of various domains of knowlegde, and the influence of personal expectations on learning (Bandura, 1969, 1971; Glaser, 1978).

Present-day cognitive psychology is oriented toward this complexity of human performance (Lesgold, Pellegrino, Fokkema, & Glaser, 1978). However, relative to behavioristic psychology, cognitive science is a fledgling, at the present time, in the application of its findings and techniques to practical human endeavors even though the development of new cognitive theories was, to some extent, motivated by applied problems. Thus, while the older behavioristic theories were developed in the laboratory and then extrapolated to practical uses, modern cognitive theory was shaped by the practical problems of skilled and complex human performance. As a result of this, a lesson has perhaps been learned: not only might laboratory work and theory be useful for application, but application can also be a significant generator and test of psychological theory. This lesson certainly has been well learned in other sciences.

2. *Research trends and questions*

The boundaries between basic and applied research are becoming increasingly blurred for many psychologists who are currently studying the educational process. Examination of recent work on the nature and development of human knowledge and intellectual skills indicates that this research is directed toward both scientific and practical understanding. An interactive network between behavioral science and education is developing and flourishing. The following brief examples illustrate this point, and I believe they indicate that in the next decade, research relevant to education will involve both strong interactions with an advancing science of human cognition, and increasingly sophisticated analyses of the conditions of schooling.

2.1. *Reading and the comprehension of text*

Reading processes have been carefully investigated in both laboratory and classroom settings. At the present time, a good deal is known about the psychological processes involved when individuals must translate printed symbols into spoken language. Children come to school with the skills of spoken language, and an important initial activity in learning to read is mastering the new visual mode of receiving language, that is, the process of decoding from print to sound. It is also true, however, that learning to read depends upon the ability to get meaning out of what is read (Beck & McCaslin, 1978). Concerning these two components of reading, decoding and comprehension, current research suggests that they are interdependent (Lesgold & Perfetti, 1978, in press), and are in conflict in the course of learning to read. Poor comprehenders display decoding deficiencies that interfere with comprehension. If too much effort is invested in decoding, the speed and ease of comprehension is impeded. Future research must assess the degree of decoding efficiency that effective comprehension demands, and a conceivable outcome of this work is the development of new kinds of diagnostic test. These tests will assess the speed and efficacy of the decoding process, and the extent to which decoding skills reach a level that permits comprehension to readily occur.

In general, there exists a useful amount of information about the initial stages of reading, but there is a dearth of knowledge about the more advanced stages of text comprehension (Resnick & Weaver, 1980; Stitch, Beck, Hauke, Kleiman, & James, 1974). This kind of skill has not been as carefully studied as the more 'mechanical' aspects of early reading. But research is increasing on these upper levels of comprehension; in particular, there is much experimental study of the use of written language as a vehicle of thought. The many interesting research questions being asked include: How do individuals use what they already know to remember and get new information from what is being read (Anderson, 1976; Bartlett, 1932; Bransford & Franks, 1971; Spilich, Vesonder, Chiesi,& Voss, 1979)? What kinds of skills are important in reading different forms and structures of text, such as newspapers, tax forms, history books, instructional manuals, etc. (Kintsch, 1977; Mandler & Johnson, 1977; Rumelhart, 1975; Van Dijk, 1977)? Can these distinctions be explicitly taught to individuals so that they can adjust and tune particular reading skills accordingly?

2.2. *Mathematical skill and understanding*

In the investigation of mathematical skill and understanding, new concepts and methods are available for analyzing in detail the nature of the cognitive processes involved. Computation and problem-solving skills are being investigated by scientists in the fields of cognitive psychology, computer simulation, and artificial intelligence. They now see the field of mathematics, with its structured and logical content (relative to other subject-matter areas), as a domain in which their work will be able to make strong contributions to instruction (Resnick & Ford, in press).

With respect to the skills of computation, the general belief that 'practice makes perfect' is being carefully examined. Practice is necessary, but not sufficient, for developing skills. Children can practice errors and misconceptions, or practice in ways that do not produce advances in skillful organized performance. Many errors occur because of the child's sensible misconceptions or use of incorrect rules and not because of a simple lack of knowledge or inattention. With this in mind, research effort is currently being devoted to the study and development of sophisticated diagnostic procedures--procedures that do more than test for correct or incorrect answers, but that assist in finding the misconceptions in children's knowledge (Brown & Burton, 1978; Groen & Parkman, 1972). Work of this kind will contribute to an understanding of systematic bases for errors that need to be monitored when a learner is reaching toward a higher stage of competence.

In the area of mathematical problem solving, certain research results indicate that a student's proficiency entails sophisticated cognitive strategies that can be recognized and explicitly taught. For example, detailed analysis of problem solving in geometry has indicated that three kinds of knowledge are involved: a) knowledge of the similarities and differences between geometric objects, such as points, line segments, angles, and so forth; b) knowledge that is used to make inferences and to prove theorems, e.g., 'corresponding angles are congruent,' or 'the sum of the angles of a triangle is 180 degrees'; and c) strategic knowledge that is used to carry out proofs, that is, to set goals, form plans, and to generally organize activity on the problem (Greeno, 1978).

In classroom instruction and in textbooks, the first two kinds of knowledge just mentioned are explicitly taught, but the third is not. The first kind of knowledge, required for recognizing the pattern of geometric objects, is usually taught through diagrams and exercises that give practice in identifying critical visual features and relationships. The second kind of knowledge, of mathematical 'rules' required in making inferences during problem solving, is also communicated through instruction in the classroom and in textbooks. However, the third kind of knowledge, strategies used in setting goals and formulating plans, is not explicitly a part of instruction in the content of geometry. This strategic knowledge is generally relegated to the student's general ability (or intelligence) to apply what is actually taught. It is possible, however, that such strategic problem solving, if it can be analyzed and understood, could also be explicitly taught. Thus, a new problem for instructional research is to study the nature of this skill and to investigate ways to teach the strategies involved so that they are fostered in students who are not able to readily induce them. Research of this kind is now seen as an important aspect of mathematics instruction and of the study of problem solving in general.

2.3. *Aptitude and intelligence*

Researchers in the field of intelligence and aptitude are uncomfortable with the current state of testing technology for a number of reasons. In general, it is clear that the intelligence tests and measures of verbal and quantitative aptitude used in schools in my country measure the kind of intellectual performance that can be most accurately called 'general scholastic ability' (Scarr, 1978). While we know that the abilities tested are predictive of success in school, we also know that the information obtained from these tests does not provide the kind of understanding that is required to encourage, enhance, or remediate these abilities for learning.

More specifically, doubts and dissatisfaction with tests that measure abilities for learning appear to stem from three main sources: a) Efforts to improve the validity of current tests have reached a plateau of efficiency with present techniques and theoretical understanding of the abilities measured. b) The tests for the most part offer minimal information that limits their utility in guiding learning. They provide information primarily useful for decisions about entrance into a program, but not useful enough to affect the conduct of instruction. In order to influence instruction, tests should be diagnostic measures that assess differences in cognitive abilities and acquired knowledge so that schools can adapt their learning environments to diverse individual needs. And c) scientists are now recognizing that current test theory and technique have not made contact with new developments in the psychology of learning and cognition.

With these concerns in mind, programs of research are being carried out that use the concepts and methods of cognitive psychology to analyze the abilities that are measured by aptitude and intelligence tests (Carroll, 1976; Estes, 1974; Hunt, Frost, & Lunneborg, 1973; Pellegrino & Glaser, 1979, 1980; Snow, 1980; Sternberg, 1977). Research efforts of this kind must be undertaken before new measures of intelligence, aptitude, and human performance can be designed. As Hunt, et al. (1973) have said, if successful, this work can change the nature of psychometric predictions from static statements about the probability of successful achievement to dynamic statements about what can be done to increase the likelihood of an individual's success in school and work. Hopefully, new concepts of aptitude and intelligence that emphasize the cognitive processes of human performance will foster the development of educational alternatives that increase individual accomplishments. I and my colleagues are at present conducting research along these lines (Glaser & Pellegrino, 1979; Mulholland, Pellegrino, & Glaser, 1980; Pellegrino & Glaser, 1980).

2.4. *School processes*

In contrast to the kind of research on cognition that I have just described, there is also a growing body of research on classroom practices and macro-instructional teaching processes. (I use the term 'macro' to contrast the level of variables studied in this area with the micro-processes of cognition (Berliner & Rosenshine, 1977; Bloom, 1976; Brophy & Everetson, 1976; Brophy & Good, 1974; Carroll, 1963; Cooley, 1978; Cooley & Leinhardt, 1975; Koehler, 1978; Stallings, 1975; Suppes, Macken, & Zanotti, 1978; Wang, 1979, 1980; Wiley & Harnischfeger, 1974).) In the past, studies designed to evaluate curriculum innovations attempted to describe school learning by relating the nature of student input to the quality of student output, and only very generally described the intervening processes. Detailed information was rarely obtained about differences between effective and less effective classroom processes in terms of some model of classroom instruction. At the present time, models are being developed that attempt to explain the variation obtained in student achievement in terms of the initial ability of the student, classroom process variables, and the interaction between the two. Work along these lines systematically defines the dimensions of classroom instruction and the components of school programs that contribute to or detract from classroom effectiveness (Wang, 1979, 1980). The use of new statistical and methodological techniques for causal analysis in observational research and field experimentation is facilitating this research. These analyses provide information for practical implementation decisions and also contribute to potential theories of classroom teaching practices.

The development that I anticipate is a macro-theory of teaching and instruction: 'macro' in the sense that it is concerned with the large practical variables dealt with in schools, such as the allocation and efficient use of time, the structure of classroom management, the nature of teacher feedback and reinforcement to the student, the organizational pattern of teacher-student interaction, the relationship between what is taught and what is tested, the degree of classroom flexibility required for adapting to learner background, and the details of curriculum materials as these relate to student achievement. Such variables need to be part of a theory of teaching in the same way that the large variables of economic theory are applied to the study of economic change. As theory at this level develops, it will be undergirded by the more micro-studies of human thinking, problem solving, and the learning of school subjects. It is possible that, in the future, the two levels, macro- and micro-investigations, will become more interrelated in studies of classroom learning and the development of human cognition.

3. *The nature of instructional psychology*

I turn now to a description of the emerging nature of instructional psychology. As I envision instructional psychology in the immediate future, I see the field focusing on the acquisition of human competence. The psychology of instruction will attempt to understand the development of the cognitive processes and structures that are indicative of the competent individual in a particular subject-matter domain or intellectual skill. The nature of competence is particularly apparent in the contrast between the beginner or novice in an area of work and the proficient expert (Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1980; Gould, 1978; Jackson & McClelland, 1979; Larkin, McDermott, Simon, & Simon, 1980; Perfetti & Roth, 1980). We must investigate the subject-matter properties, environmental conditions, and individual differences that influence this acquisition of competence, and understand the changes that take place as an individual progresses from relative ignorance to increasing levels of knowledge and skill.

The changes that take place as skill and knowledge develop are quite amazing and include such changes as the following: a) Slow, crude, and variable performance changes to performance that is consistent, apparently automatic, fast, and precise. This change is particularly apparent when an individual develops competence in computing with numbers and reading words. b) Small unitary responses and step-by-step algorithmic procedures change into large integrated units of performance. An example of this is learning to ride a bicycle or learning to consider an opponent's move on a chess-board. c) Reliance upon the perception of specific surface features of a problem situation changes to holistic perceptions that are guided by the underlying principles. The expert shows decreasing dependence upon the concrete overt features of a problem situation and developing skill in increasingly abstract rule-governed performance. This occurs in learning to solve problems in physics, mathematics, engineering, and other subject matters. Certain details of this change have been carefully studied in solving problems in physics (Larkin, et al., 1980; Simon & Simon, 1978; Chi, et al., 1980).

3.1. *Components of a psychology of instruction*

A major focus of the new psychology of instruction will be the understanding *and* facilitation of such changes in cognition and performance that occur as an individual moves from novice to expert. Research devoted to analyzing the transition to competence can be approached in terms of several integral components. These are: the nature of competent performance and of intermediate performance states, the initial performance state of the learner, the transformation processes between this initial state and a state of competence, and the monitoring and assessment of performance changes (Atkinson & Paulson, 1972; Glaser, 1976). I shall comment briefly on each of these components.

First, *competent performance.* Analysis is required of the structures and processes of knowledge and skill that comprise objectives of instruction, and that characterize high knowledge, well-skilled individuals. The analysis involves two related aspects: the information structures and declarative knowledge that are required for performance, and the cognitive strategies and procedural knowledge that are applied to this information. Individuals solve problems effectively because they employ efficient processes *and* because they rapidly access the appropriate information. The interaction between these two aspects is important to consider in the analysis of competent performance. Specification of the psychological processes and forms of knowledge to be attained in the course of instruction is an essential task in determining optimal instructional procedures for individuals, and the theories and techniques involved in analyzing the details of competence and its growth are now undergoing intensive development. The results of this work will help specify the sequence of intermediate states that can be identified as increasing knowledge and skill is attained.

The second component integral to understanding the acquisition of competence is specification of *the initial state of the learner.* Instruction begins with the learner's initial knowledge and skill and proceeds forward from this base. The analysis and assessment of initial state performance provides information for improving instruction. Too often, this information is used to classify and label individuals for general educational assignments, and is not used in a diagnostic fashion for optimizing instruction. Initial state characteristics facilitate or retard the learning of subject-matter competence. They are comprised of general and specific subject-matter skills that can assist in learning and that are transformed into more advanced states of competence. Initial state also consists of skills of knowing how to learn.

The initial state of the learner has been considered in educational practice in a number of ways. One is assessment of the ability to learn through the use of aptitude and intelligence test scores that are predictive of achievement. A second is the diagnostic assessment of a student's strengths and weaknesses in a subject matter, which might be attended to in remedial programs. A third, particularly with children, is the assessment and training of readiness skills that reflect the developmental level required for beginning instruction, e.g., sound and symbol discriminations involving perceptual and language competence. These three aspects refer to related characteristics of an individual's performance. And instructional psychology needs to consider experimental and theoretical work that is concerned with the detailed analysis of these influences upon learning.

The third component is *learning and state transformation processes.* Given information about the end-state competence to be attained and the initial state characteristics of an individual, this component of the instructional process involves the conditions for admissible transformation from one state to another, i.e., conditions for learning that can be implemented to foster the acquisition of competence. The implementation of these conditions includes the various instructional procedures, techniques, and materials used by the learner and the teacher, factors that are designed into the environment in which learning occurs. In some sense, all environments in which knowledge and skill are developed are 'designed.' Conditions that foster or retard knowledge and skill are present whether instruction is very deliberately designed or whether the decision is made to let things develop 'naturally and spontaneously.' But even in the latter case, an instructional setting is designed by default. In any event, the task of instruction is the deliberate design of conditions for the acquisition of performance based on some theory of learning. These may be intuitive theories developed over the years by an experienced teacher or an experienced self-learner. And they may be notions of instruction designed into a teaching device or theories of learning constructed by psychologists.

A central interest in this regard is how the problem of transition is solved by various conceptions of learning. Different psychological theories have suggested, directly or indirectly, how conditions might be implemented to foster the transition of states of performance to higher stages of competence (Glaser, 1980). For example, growing out of behavioral theory, three major attempts have been statistical learning models and their techniques of optimization (Atkinson, 1972, 1974; Atkinson & Paulson, 1972; Chant & Atkinson, 1973; Groen & Atkinson, 1966), the programmed instruction paradigm (Glaser, 1978; Lumsdaine, & Glaser, 1960; Skinner, 1958), and theories of learning hierarchies involving transfer relations between prerequisite stages of intellectual skill (Gagné, 1968, 1977; Gagné & Paradise, 1961). More recent cognitive process theories have suggested instructional strategies using mediation and mental elaboration procedures in learning a second language, goal setting and planning knowledge in mathematical problem solving (Greeno, 1978), and analysis of the sequence of rule-governed behavior in the development of scientific knowledge (Siegler, 1976, 1978; Siegler & Klahr, in press). From work in artificial intelligence, structural network theories have provided techniques for the analysis of information structures in the form of networks of facts, concepts, and procedures that are acquired by students over the course of computer-assisted tutorial instruction (Carbonell, 1970).

The fourth component is *assessment and monitoring*. As individuals attain new levels of performance, assessment is required to monitor the characteristics of new knowlegde and skill. This requires measurement techniques that assess the properties of what has been learned. The primary function of assessment is to provide information that can feed back to alternative instructional procedures. For effective assessment of this kind, measurements need to be interpreted in terms of criteria of performance so that discrepancies between desired and attained states can be ascertained (Glaser, 1963; Glaser & Klaus, 1962; Glaser & Nitko, 1971). In this way, a controlling function is set up that informs that instructional system, the teacher, and the learner about progress relative to the processes and knowledge structures defined as components of competence.

The assessment techniques that are required for this purpose are derived from detailed task analysis of the intermediate states in the acquisition of competence. As more is known about the stages of competence in acquiring skill, the more comprehensive will be these assessments. The usual test scores that provide information only about an individual's relative standing in a group of learners (like percentile ranks and other norm-referenced measures) will not provide the detail necessary for making appropriate decisions. The development required in the context of a theory of instruction is the design of diagnostic procedures that identify components of successful and unsuccessful performance. These diagnostic measures should identify faulty information structures and procedural knowledge that contribute to incorrect performance. New measurement techniques based upon longitudinal studies should also be developed that identify the performances of individuals that facilitate or interfere with the attainment of eventual higher levels of competence.

To summarize, the forgoing four components of a psychology of instruction comprise a framework for future research and development work in this field. Theory and experiment should be carried out that relate to each component and to their coordination as an instructional system. These components can be viewed as the typical components of rational problem solving in many domains. These are: specification of the goal state to be attained; specification of the initial state of affairs; admissible operations that will transform initial state into the goal state; and then, assessment of the intermediate states that are subgoals that need to be monitored to provide information for alternative transition operations.

3.2. *Some guiding principles*

As research on these components of instructional psychology is undertaken, I propose five principles to guide these investigations so that they result in knowledge that contributes both to theories of cognition and learning, and to the development of instructional practice. If this can be accomplished, then instructional psychology will be the 'linking science' envisioned by Dewey, enriching both psychology and education.

a) *Attention to both performance and learning.* Modern cognitive psychology, with support from artificial intelligence and computer science, has emphasized primarily the processes that describe performance in a particular task situation. Less work in modern cognitive theory (in contrast to older behavioristic theories) is devoted to the mechanisms of learning and to transitional processes of performance state change. New work that emphasizes learning processes and the acquisition of performance is essential to the design of instructional conditions.

   A caution that needs to be made, however, is that most learning theories to date are based on investigations of time spans that are long enough only for experimental convenience, and not long enough to consider the extensive periods of acquisition – many hours and years of learning and experience – that are required in real life for the attainment of high levels of skill.

b) *Knowledge-domain orientation.* Instructional psychology is constrained by the goal of contributing to education and training. Thus, a theory of instruction cannot depend on artificial laboratory tasks, but must be knowledge-domain specific. The experimental tasks studied should increase our understanding of the skills of literacy: decoding and comprehending printed text, acquiring language, learning to write and to compose, performing arithmetic computation and mathematical thinking, and the utilization of knowledge in problem solving. Experimentation and theory on the acquisition of competence must be considered in these contexts, and accept the problems that these subject-matter contexts impose.

c) *A normative, prescriptive theoretical approach.* The traditional work of psychological theory has been the scientific investigation and description of human performance. Building upon and contributing to this objective, instructional psychology must also design systems capable of generating conditions that can foster the *acquisition* of performance. Instructional theory, then, must have the characteristics of a prescriptive science of design. It will rely upon the traditional sciences to describe how things are and how they function. But its unique activity is to prescribe and design conditions for learning based upon this information. In considering the possible shape of a prescriptive theory of instructional design, some leads are provided by the optimization methods developed in other fields to devise courses of action aimed at changing existing situations into preferred ones (Atkinson & Paulson, 1972).

d) *A theory oriented toward the individual.* Psychological theory has been concerned primarily with discovery of general laws that have taken little account of individual differences. Historically, the experimental study of learning and cognition, on the one hand, and the study of differential psychology and psychometric techniques, on the other, have been separate disciplines. In contrast, instructional theory must take into account individual differences and individual initial states of performance that should be adapted to in the design of conditions for learning. Progress along these lines is encouraged by the fact that much current theorizing in cognitive psychology derives from the study of single individuals performing in task situations. Discovery of the communalities and regularities of human cognition is approached through the study of modeling individual performance rather than through the statistical averaging of individual cases to determine general laws as was done in older learning theories.

e) *A cybernetic decision-theoretic system.* An especially significant aspect of an instructional system is the fact that the characteristics of performance at any state in the course of learning can become the basis for deciding upon further instructional conditions. This constant dynamic aspect of instruction adapts to individual progress, and the operations selected to facilitate learning depend upon the difference between current performance levels and standards of performance to be attained.

4. *Conclusion*

Education can no longer be content to be a major profession in our society whose practices are little influenced by developments in science and technology. This state of affairs is no longer tolerable under the press of the current problems of education and is no longer possible in the light of the recent developments in the behavioral and social sciences.

In the past 15 years, these sciences have moved strongly into the study of skilled and complex human performance and into the analysis of instructional processes relevant to the educational enterprise. Reading and mathematics ability, aptitudes for learning, and skills of thinking and problem solving are being studied with powerful new techniques. Researchers are obtaining increased understanding of the influence of conditions of schooling upon the development of essential literacy and intellectual competence in children and adults.

Two sources of information – increasing understanding of human cognition and learning, and analysis of the processes and outcomes of schooling – will undoubtedly influence policies and patterns of education. In the future, it seems likely that the educational profession will begin to receive the scientific support that should underlie one of the major functions of society. Certainly a basic science of behavior is necessary for a theory of instruction. And behavioral scientists are more aware that the development of an effective theory of instruction is a strong way of assessing the limitations of scientific knowledge.

Finally, it seems to me that, in many respects, psychology and education are returning to the closeness they enjoyed in the early part of this century, before psychology departments and schools of education went their separate ways. There will be a renewed interdependence, and as a result, we will see many of the persistent problems of education in new ways.

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R. Glaser (1921) is University Professor of Psychology and Education aan de University of Pittsburgh. Hij was medestichter en is thans co-directeur (met Prof. L. B. Resnick) van het Learning Research and Development Center, dat aan de University of Pittsburgh verbonden is en in 1964 als één der eerste instituten opgenomen werd in het Amerikaanse netwerk van federaal gesubsidieerde universitaire centra voor onderwijskundig onderzoek en ontwikkelingswerk.

Prof. Glaser was in 1971-72 President of the American Educational Research Association. In 1976 ontving hij de AERA Award for distinguished contributions to research in education. Hij schreef ongeveer 150 wetenschappelijke artikelen en hij is auteur of redacteur van een negental boeken waarvan er enkele vertaald werden in het Duits, het Japans en het Spaans. We vermelden slechts zijn werk van 1977 *Adaptive education: individual diversity and learning*. (New York, Holt, Rinehart & Winston) en het feit dat in 1978 het eerste volume verscheen van de nieuwe reeks *Advances in instructional psychology* (Hillsdale, Erlbaum), waarvan hij de redactionele leiding waarneemt.

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