The purpose of the contract was to study the psychological characteristics and instructional factors of skill acquisition in jobs requiring high levels of expertise. One of the goals of the work was to examine the acquisition of competence in skills that require hundreds or even thousands of hours of instruction and practice. This work was carried out by a collection of several separate research projects which were combined into a single grant for the convenience of the government. Each of these separate projects has reported at length about its work, in archival publications, extended status reports to ONR, technical reports. This final report is a compilation of information about the many outcomes that have been separately published.
Cognitive and Instructional Factors in the Acquisition and Maintenance of Skill:

Final Report to the Office of Naval Research on Contract No. N00014-79-C-0215, NR 157-430

This is a final report of the activity on Contract No N00014-79-C-0215, NR 157 430, which was awarded to the Learning Research and Development Center, the University of Pittsburgh, by the Personnel and Training Research Program, Psychological Sciences Division, Office of Naval Research.

The purpose of the contract was to study the psychological characteristics and instructional factors of skill acquisition in jobs requiring high levels of expertise. One of the goals of the work was to examine the acquisition of competence in skills that require hundreds or even thousands of hours of instruction and practice. This work was carried out by a collection of several separate research projects which were combined into a single grant for the convenience of the government. Each of these separate projects has reported at length about its work, in archival publications, extended status reports to ONR, and technical reports. This final report is a compilation of information about the many outcomes that have been separately published.


Derives principles of skilled performance from the literature of cognitive skills and uses a map-drawing study to explore a critical component of spatial knowledge. The study concludes that normalizing errors in large-scale environments are caused by incorrect representations at higher levels in the knowledge hierarchy. Also addresses the question of what cognitive processes underlie cognitive maps and cognitive mapping from an information-processing analysis of spatial knowledge.


How effective is the teaching of a new cognitive strategy? The teaching of decontextualized strategies is now thought to be ineffective. This study demonstrates that children can benefit from instruction on the use of a new strategy in a domain provided that their previous knowledge of the domain is coherent and well organized. More generally, the experiments suggest a relation of interdependence between knowledge and strategies.

An investigation of problem solving skill in physics through experiments that contrast experts' problem-solving procedures with novices'. Experts and novices were found to begin problem representation with specifically different problem categories. Their categorization depended on different knowledge. Novices' representations of the problems depended on literal features of the problem, such as the apparatus named, while experts' representations were based on the physics principles underlying the problems.


A review of the state of our current understanding of human problem solving, with particular attention to the fact that effective problem solving requires well-structured, domain-specific knowledge. The need to study ill-structured problems, the kind most often encountered in the "real world," is discussed.


How can the new understanding of human thinking and problem solving contribute to instructional practices? Efforts to improve the skills of reasoning and problem-solving are considered in the light of current theory and findings in cognitive science. After discussion of the interaction between the development of problem-solving and learning skills and the acquisition of structures of domain-specific knowledge, suggestions are made for developing thinking abilities in the course of acquisition of domain-specific skill.


Explores hypotheses about ways in which representational knowledge influences problem solving. The author discusses empirical findings and theoretical analyses in support of his hypotheses about the importance of the ontology of problems (what entities are included in the representation of the problems). He indicates that the ontology of a problem may affect the solving process:

- by making analogies between domains more or less difficult;
- by determining what information will be available for general reasoning procedures;
- by determining what kinds of information can be read out directly and what kinds will need to be computed;
- and by determining the entities available in an early stage for planning.


This paper presents a framework for characterizing competence for cognitive tasks. It is proposed that competence has 3 main components: conceptual, procedural, and utilizational competence. Conceptual competence is considered in particular detail. The use of the framework is exemplified by a detailed examination of children's counting performance.


Reviews the roles of knowledge, automatized skill, and strategy in expert performance. Gives special attention to the importance of initial problem representations in expertise and to capacity limitations that impede their use by those with intermediate levels of skill. Discusses strategy in the light of the importance of specific domain knowledge. Makes suggestions for the development of a theory of coaching that is informed by emerging psychological account of expertise.


A review of the Handbook and an essay in response to it. Concludes that it is critical to our society to discover how to teach hard-to-teach skills, including learning skills.


Jobs that require the least training and the least flexibility are the most likely to be lost to automation. Automation also destroys apprenticeship opportunities. Therefore, the skills that are most likely to continue
to be useful are those that require such qualities as flexibility, opportunistic learning and the interpersonal skills of leadership and collaboration. Such skills characterize human expertise, as shown, for example, in studies of radiological diagnosis. Computers can be valuable tools for the large-scale and long-term research necessary to understand human expertise in order to develop effective instruction in these difficult-to-teach skills.


An exposition of current knowledge of problem solving: how problem solving is studied and simulated for well-structured problems; human processing limitations; representing problem solving in production systems; expertise in problem solving; the acquisition of skill in solving problems; John Anderson's learning theory applied to the acquisition of problem-solving skill; practical applications of theory; creativity in problem solving.


Interprets findings that, across several countries, performance on "change," "combine," and "compare" addition and subtraction word problems showed consistent patterns of performance. Emphasizes the development of empirical, logical, and mathematical knowledge for skilled performance.


Addresses the problem of improving aptitude for learning through instruction, by focusing on the skills necessary for learning from instruction, in particular, for induction. Describes study of successful and unsuccessful attempts to solve verbal, figural, and numerical analogies suggesting that the factors that differentiate skilled from low-skill performers include management of memory load, organization of an appropriate declarative knowledge base, and procedural knowledge of task constraints. The implications for testing and instruction are discussed.


Describes studies that suggest that children's development of skill in solving arithmetic word problems primarily involves an increase in the complexity of conceptual knowledge--knowledge that is required to represent the situations described in the problems. Considers general issues in the development of problem-solving skill.

Technical reports.


Surveys the state of understanding of human problem solving, with particular attention to the roles of

- initial problem representation
- specific knowledge of a domain
- the structure of domain knowledge
- the representation and solution processes for ill-structured, real-world problems.


Consistent differences in performance among medical diagnosticians at different levels of experience in subspecialties were found in diagnostic tasks recorded in think-aloud protocols. Recurrent sources of error (bugs) were identified for the less experienced diagnosticians.


A study of diagnostic skill in radiology. Five expert radiologists (10+ years’ experience past residency) and eighteen residents in radiology were given chest films to diagnose. Analysis of their think-aloud protocols suggests that experts build rich mental representations of the patients’ anatomy, to invoke patterns of disease that constrain the interpretation of ambiguous features, and to seek and respond to new data.


END
DATE
FILMED
DTIC
July 88