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ABSTRACT

This paper presents a perspective of the current state of technology-assisted instruction integrating computer language, artificial intelligence (AI), and a review of cognitive science applied to instruction. The following topics are briefly discussed: (1) the language of instructional technology, i.e., programming languages, including authoring systems; (2) technology assisted instruction using AI, including the formal study of AI in computer science and current applications of AI in education, industry, and high-technology fields; (3) AI principles applied to instruction, including the three components of the operational functions of an AI system, i.e., expertise module, student-model module, and tutoring module; and (4) a cognitive science paradigm applied to instruction, including computer based instructional (CBI) characteristics of systems that exhibit elements of machine intelligence and the development and characteristics of the MAIS (Minnesota Adaptive Instructional System). (22 references) (CGD)

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Overview

This article will present a perspective of the current state of technology-assisted instruction integrating computer language, artificial intelligence (AI)) and a review of cognitive science applied to instruction.

In the past decade the availability of the microcomputer in educational technology has increased at a phenomenal rate. Today almost every student in the United States has access to a microcomputer. Routinely, instruction is included in the curriculum on computer literacy and higher level languages such as BASIC, LOGO, PASCAL and C. The age of the microcomputer and enhanced educational technology has arrived. At least, the technology has arrived; unfortunately the hardware appears to lead the market, while use of the technology for improving learning lags far behind. Courses on computer literacy, languages, and the relatively few good educational software programs are beneficial, however, these courses do not meet the tremendous potential that educational technology offers in assisting educators and researchers in the quest to improve learning.

The need for basic research using this technology along with its essential attributes is of paramount importance if the situation described above is to be improved substantially. No longer are educators, students and parents going to be elated with fancy graphics, a barrage of games, and relatively useless computer programs that do little more than a workbook. The goal of the use of the microcomputer and technology should be one of improving learning based on sound educational theory.

The Language of Instructional Technology

A programming language (to include authoring systems) has at least three goals: 1) it is a design tool; 2) it is a vehicle for human communication; and 3) it is a vehicle for instructing a computer.

In the first of these goals, the programmer or designer must determine an overall strategy that will accomplish the instructional objectives. The designer must choose a structure that will be correct, efficient, and amenable. For practical reasons, the design is restricted by hardware (memory, processor, secondary storage, and language). When the process of design becomes more defined, the computer language becomes more important. The language shapes the way in which the designer thinks about problems, as does the computer language chosen. Programming languages serves as a communication medium between designer and program. First a designer must delineate what the intended instructional program is to do. Too often the language will make the designer/programmer concentrate on the "how" instead of the "what". The ability to understand this paradox is crucial. The question is should every conceivable useful construct be contained in the language or should the language contain the constructs that are just right for the program/problem at hand? This decision should be based on the competency of the designer and the purpose of the instructional program. The computer must be given the instructions if the program is to run with reasonable space, time and efficiency. The above would seem to be an relatively easy problem to deal with. The reality is that what is reasonable in a language is not always efficient. Difficult and unexpected efficiency problems typically arise not from a single language feature, but rather from a combination, an interaction of several features, in which each feature seemed reasonable by itself. Choosing the proper balance between features is what has often turned out to be more difficult than expected. Software. Basically the requirements of software can be thought of in four areas: degrees of software complexity, degree of software structuredness, degree of software requirements, and degree of software reliability.

Technology Assisted Instruction using Artificial Intelligence

The formal study of AI in computer science can be trace to the early 1960s (Feigenbaum & Feldman, 1963). The focus was on the design of computer programs that would enhance decision making, as well as storing and retrieving information. Early attempts in cognitive science to simulate the brain with computer models stimulated interest in how to simulate decision making by experts (Amarel, 1969). The application of AI in education came through cognitive science research on problem solving (Tennyson, 1982); For the last decade, artificial intelligence has generated strong interest and enthusiasm in industry and universities; it has become an important component for research and development in high-technology fields. The phrase "Artificial Intelligence" seems randomly applied in a wide variety of contexts by a growing number of people from diverse backgrounds. At issue is the nature itself of what is called intelligent,let alone whether a machine can be intelligent (Schank,1980),(Whaland, 1981),(Weizenbaum, 1977) ,(Green, 1984). A question arises of whether rules and maxims of a general nature exist and whether they are applicable across domains (Goldstein, 1975), (Simon, 1969), (Glasser, 1984). Other issues related are the questions of can a machine emulate human intelligence, or is human intelligence emulation necessary (Hayes-Roth, 1977)? The public perception has focused on the "artificial".

Computers (machines) are performing feats that we never dreamed of. The computer science community is constantly expanding the usefulness and power of their machines. This fact is important in science and engineering, but not in AI.

Most good AI programs aren't terribly useful, and many useful, "smart": programs aren't AI at all. If this distinction were understood, we could avoid a lot of confusion and disappointment (Schank, 1980).

Artificial Intelligence Principles Applied to Instruction

AI systems can take many forms, but essentially they arrange various components of an instructional system by using AI principles and techniques in a way which allows both the student and the program flexibility. However, in most applications AI systems act on the basis of preentered questions, anticipated answers, prespecified branches, and to some extent on the structure of domain knowledge and the student's representation of the knowledge (Feigenbaum, 1977), (Brown, 1977).

Natural language has become an important feature of many AI systems, thus, allowing the student to generate questions and corresponding answers through a natural dialogues with the system. (Carbonell, 1970), (Waldrop, 1984), (Rosenberg, 1977). The goal then of AI systems is to improve decision making, improve learning, while increasing the accumulation of knowledge with experience (Nelison, 1971),(Tennyson, 1984). How this goal is reach and by what method, and how effectively the system operates becomes the essential question in evaluating AI systems. The operational functions of an AI system can be determined by three main components: The content (or information to be learned, the instructional strategy, and a mechanism for understanding the student's current knowledge state. These components are referred to as the expertise module, the student-model module, and the tutoring module (Clancey, Barnett & Cohen, 1982). Ideally, an expertise module should have its own problem-solving expertise as well as static knowledge of the subject matter; a student-model should have its own diagnostic capabilities, and the tutoring module should be able to provide intelligent learning guidance with its own explanatory capabilities (Tennyson & Park, in press). Early AI system mainly focused on representation of the domain knowledge. Since the mid-1970s, however, modeling the students' learning behavior and tutorial strategies for presenting the materials have been some of the main issues in the development of AI systems (Sleeman & Brown, 1982).

Cognitive Science Paradigm Applied to Instruction

Given the memory and calculation capabilities of computers, it is possible to consider Computer Based Instructional (CBI) systems that exhibit elements of machine intelligence (that is, the ability to use new information to update files and refine the decision-making) in contrast to conventional CBI systems which offer only "dumb" management systems (for example, branching or looping programs that only consider at-the-moment information). Intelligent Computer Based Instruction can be characterized as follows: (a) provides an initial diagnostic assessment of each learner in reference to a given learning task, followed directly by a prescriptive instructional treatment; (b) gives a continuous, on-task assessment that iteratively updates the diagnosis and prescription; (c) determines the amount of instruction based on learner progress toward mastery of the learning objectives; (d) selects the sequence of instruction by a response-sensitive strategy according to cognitive processing needs; (e) adjusts the moment-to-moment instructional time so as to reduce off-task learning time, thereby improving the on-task learning time ratio; and (f) provides continuous advisement to the learner on learning progress and learning need(s).

Initial work on the MAIS began in reference to designing an adaptive instructional strategy for concept-learning (Tennyson, 1975). The combined work on adaptive variables and concept-learning has evolved into two major lines of inquiry -- both independent but highly supportive of the other. As investigations of the phenomena of concept-learning and rule-learning progressed, the sophistication of the MAIS has increased along with the understanding of human factors interacting with computer technology. The concept-learning theory followed in the empirical testing of the MAIS is a two-stage process of prototype formation and classification skill development (see Tennyson & Cocchiarella, in press). Concept-learning is fundamental to the acquisition of knowledge and the development of problem-solving skills; thus it is highly important that learners successfully acquire conceptual information in as effective a manner as possible (Shumway, White, Wilson, & Brombacher, 1983). From the beginning of the research, it was recognized that attributes of the computer had the potential for handling the instructional variables necessary for concept teaching while meeting the goal of attending to individual differences. This adaptive instructional system is formed from the interaction of learning theory, structure of information, and attributes of the computer-based delivery system.

The main variables of the MAIS are six conditions of instruction: a) amount of instruction, b) sequence of instruction, c) display time interval, d) advisement, e) embedded refreshment and remediation, and f) format of information (examples). The above conditions of instruction represent the means by which the MAIS interacts with learning theory, information structure, and delivery systems. The philosophy of the MAIS follows a cognitive psychology theory of learning that applies specifically to the memory processes of information storage and retrieval. Briefly, the cognitive learning theory of the MAIS holds that knowledge acquisition is best accomplished through experience -- both of an expository (statement) form and interogatory (question) form; also, that using knowledge for problem-solving and creative thinking requires practice. Furthermore, learning is viewed as a range of cognitive processing proceeding from the acquisition conceptual knowledge and skills to, finally, acquisition of the ability to generate new knowledge (productive thinking).

Formally designed and controlled instructional systems seem to offer the best means for facilitating learning during the initial and transition stages, while less formal systems offer more suitable means for the higher levels of productive thinking. In operation, the MAIS focuses on the transition area of learning (especially, the learning of concepts and rules), although the intention is that the MAIS offers a more efficient means for the initial acquisition of knowledge. Because learning at the highest level of cognition is not the acquisition of new, external knowledge but the use of existing knowledge in productive thinking, other less structured instructional experiences seem to be more appropriate (for example, computer-based simulations). The remainder of this section will define the theoretical basis of the MAIS according to each of the conditions of instruction.

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