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ABSTRACT

The third of four symposium papers argues that, if instructional methods are to improve learning, they must have two aspects: a direct trace to a specific learning process, and empirical support that demonstrates their significance. Focusing on the tracing process, the paper presents an information processing model of learning that can be used by educators to determine whether specific computer-based media variables and methods may improve learning. Six basic educational components necessary to trace media variables to learning processes are then discussed: (1) learning processes, specifically the long-term memory systems of storage and retrieval; (2) learning objectives; (3) the knowledge base of information to be learned; (4) instructional variables, or the means of instruction by which information is communicated to the student; (5) instructional strategies; and (6) computer-based enhancements. Instructional strategies for improving the learning of declarative knowledge (knowing what), procedural knowledge (knowing how), conceptual knowledge (knowing when and why), differentiation, integration, and creation are also considered, including such computer-based enhancements as drill and practice, intelligent instructional systems, and problem-oriented simulations. In conclusion, it is noted that additional basic research in instructional technology is needed to provide support for understanding the role of media in improving learning. A 29-item bibliography is included. (MES)

Computer-Based Enhancements for the Improvement of Learning

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Computer-Based Enhancements for the Improvement of Learning

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For the past 20 years a major debate in the field of educational technology has been the two part question: "does media improve learning?", and if so, "by how much?". Early on, proponents of an affirmative answer based their opinions solely on technocratic assumptions. This group is still alive today but with increased support form the hard technologists (i.e., computer scientists) which offer such "new" technologies as microworlds, "intelligent" computer-assisted instruction (ICAI), and expert systems. Those educators who answered with a negative, based their conclusions basically on methodological grounds. They argued first that research findings in favor of the question were flawed in both experimental design and methodology. Given the academic approach to their criticism, the opponents only achieved recognition in a limited circle of educationally based research programs. And, with the rapid development of computer technology following the application of the mirco-clip in the later 1970s, the questions no longer seemed relevant. That is, it was assumed to have been answered in the affirmative by the advancement of technology.

However, by the mid-80's, educators by increasing numbers began to realize that maybe the question needed to be reconsidered given the apparent decline in computer popularity as the solution to the crisis in education. Once again though, the technologist have been successful in fending off the opponents because of several hardware (e.g., interactive video) and software (e.g., LOGO) developments. But, as the new technological "solutions" continue to fail or to be replaced by yet another educational panacea, opponents are still raising the question a new. And as the new technologies become even more sophisticated, the question is actually becoming more important.

The purpose of this presentation is not an answer to the question, but to elaborate on the question and to offer a view that is at the same time a yes and a no. The problem seems not to be the technology, but the failure of proponents to adequately trace the variables of their respective media techniques to clearly defined learning processes. For example, LOGO is suppose to improve thinking skills simply because the student is engaging in a technology-based discovery system. Although proponents of LOGO claim some foundation in neo-Piagetian learning theory, they, for the most part, have invented a set of terms beyond the scope of Piaget's theory which focuses on experience and effort in learning. Piaget emphasized active engagement in the domains of information, not artificial environments divorced from real knowledge.

To illustrate this concept of tracing media-based variables to the improvement of learning, I will concentrate on the program of research that my colleagues and I have been working on since 1971. There are of course other researchers and centers of programmatic research which further illustrate this concept of media research founded in learning theory: for example, Joseph Scandura, Robert Glaser, David Merrill, Paul Merrill, Richard Clark, Steve Ross, and Gabriel Solomon.

Tracing Model

In this article I will discuss six basic educational components necessary to trace media variables directly to specific learning processes. Because of the focus of my research on computer-based variables, I will not include other media forms (e.g., video and print). The purpose of this article is not to explain in detail all of the components, but to propose that an answer to the question on media and improved learning can be done in part by showing the direct of linkage media variables to specific learning conditions and processes.

Infor ation processing model of learning. In my research program, the basic learning theory is directly related to a information processing model. This model has been defined in several sources (Tennyson, 1978; Tennyson, in press; Tennyson & Christensen, 1987). The model includes these system components (Figure 1): (a) the receptor component by which external information is entered into the brain; (b) the perception component where the information is filtered according to individual criteria; (c) the short-term/working memory component which has a dual function. The short-term memory deals only with information at the given moment and does so with no cognitive effort for encoding. Working-memory on the other hand engages directly with long-term memory to encode information into the current knowledge base; (d) the long-term memory component which consists of the storage and retrieval systems. The storage system codes information according to specific types of knowledge (i.e., declarative, procedural, and conceptual) while the retrieval system involves the thinking skills associated with differentiation and integration; and (e) the cognitive process of creating knowledge within the cognitive system itself.

Insert Figure 1 about here

Components of Tracing Model

Table 1, shows the six main components usually associated

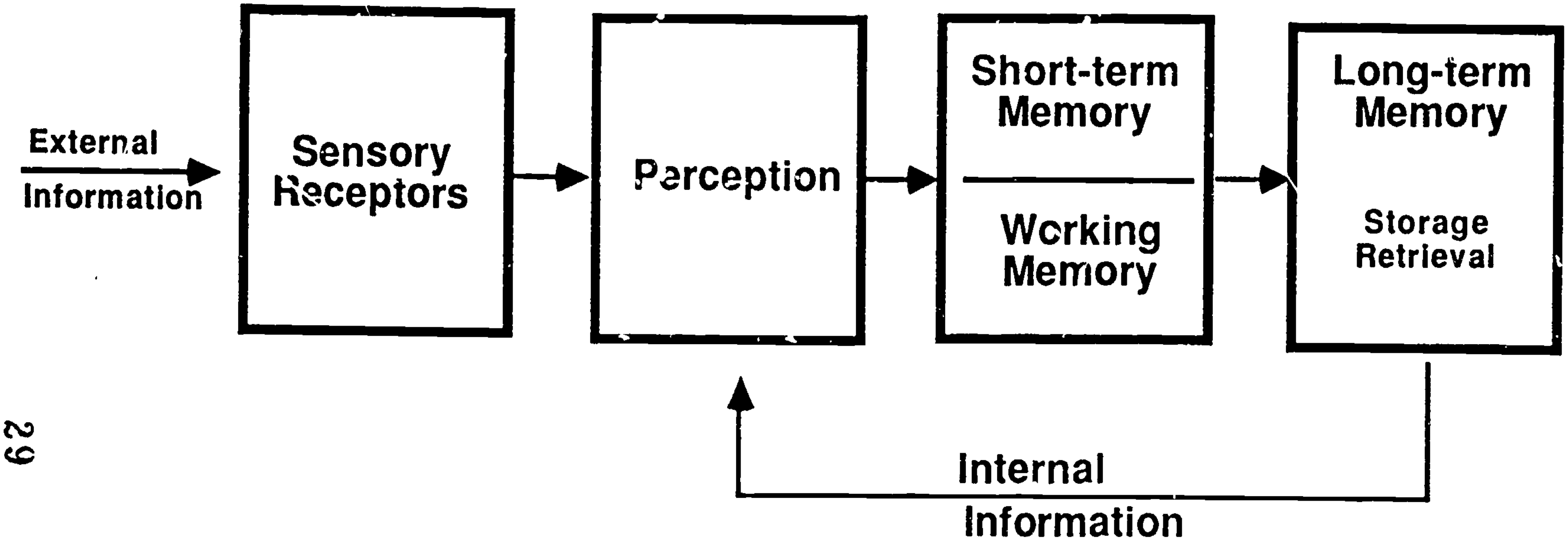

Figure 1. Meta-Learning Model.

with the instructional design (ID) process. In practice, however, the links between the components are neither well established operationally or theoretically. My purpose here is to both illustrate and discussion the linkages to propose that media can improve learning when it is viewed as an integral component of the entire ID process.

Insert Table 1 about here

The six components are:

-Learning Processes. The focus here is on the long-term memory systems of storage and retrieval. Storage system refers to the learning processes associated with knowledge acquisition (i.e., the encoding and coding of information) while retrieval system refers to the skills of thinking (i.e., recall, problem solving, and creativity).

-Learning Objectives. The purpose of education is to result in student learning (i.e., knowledge acquisition and thinking skill development). Objectives are necessary to identify the type of learning that is desired. The objectives should be linked to specify learning processes.

-Knowledge Base. Analyzing the information to be learned involves not only the basic content but also the structure of the information as knowledge in memory.

-Instructional Variables. The means of instruction are the variables by which information is communicated to the student. In Table 1, I present those basic variables which have been empirically tested to improve learning. The variables are directly linked to their respective primary learning processes. Certain variables may also have secondary links to other processes.

-Instructional Strategies. The instructional strategies identified here only represent those which I have tested in my research program. And, in most situations, employed computers in some capacity.

-Computer-Based Enhancements. The enhancements listed here are sub-divided into categories according to their intelligence in decision making. Conventional computer-based instruction (CBI) uses branching techniques that are determined in the design stage and are preset in the program. Intelligent CBI are rule-based programs that make decisions at moment the student is learning: Thus, they adjust moment to moment to individual differences.

Tracing declarative knowledge. In general terms,

Table 1: Tracing Learning Processes to Computer-Based Enhancements

Learning Processes (Long-Term Memory)	Learning Objectives	Knowledge Base	Instructional Variables	Instructional Strategies	Computer-Based Enhancements	
					CONVENTIONAL (branching)	INTELLIGENT (rule-based)
STORAGE SYSTEM:						
Declarative Knowledge (knowing what)	Verbal/Visual Information (awareness and understanding of concepts, rules, & principles)	Schema Characteristics (content: objects, events, & situations)	Label Definition Best Example Refreshment Expository Examples	Drill & Practice (e.g., rhearsal, repetition) Lecture	Replacement Ratio Worked Examples Graphics	Embedded Refreshment & Remediation Mixed Initiative Advisement
Procedural Knowledge (knowing how)	Intellectual Skills (ability to employ concepts, rules & principles)	Schema Structure (context organization: algorithm or heuristic)	Interrogatory Examples (divergent) Attribute Elaboration	Tutorial (e.g., PI, CAI, ICAI, peer tutor)	Format of Examples	Amount of Information Learning Time Corrective Error Analysis Sequence of Information Process Feedback
Conceptual Knowledge (knowing when and why)	Conditional Information (ability to perceive criteria, values & appropriateness)	Schemata Structure (network associations & rules: taxonomy, category, & hierarchy)	Context (problem) Advanced organizer Feedback Strategy Information Cooperative Learning Group Techniques (heterogeneous)	Task-Oriented Simulations	Adjustment of Variables & Conditions	
RETRIEVAL SYSTEM						
Differentiate Integrate Create	Cognitive Strategies (Develop skills in recall, problem solving, & creativity)		Cooperative Learning Group Techniques (homogeneous)	Problem-Oriented Simulations		Elaborateation & Extension of Variables & Conditions

declarative knowledge means "knowing what." For example, the student knows that underlining keywords will improve recall. The learning objective for this learning process is verbal/visual information. What the student learns is both an awareness and understanding of concepts, rules and principles. For example, the student is aware of certain strategies for recalling of information from text. The knowledge base (KB) in my context employs a schema theory application. With this form of learning, the KB identifies the schema characteristics of the knowledge. Characteristics include the objects, events, and situations of a schema. For example, the student has a schema of underlining keywords of scientific text.

The instructional strategies for improving this learning process include variables directed to information that is specific, and perhaps, finite. The variables label and definition provide the location and connection of information in a KB. When a connection is difficult to establish, the refreshing variable focuses on the need for review of appropriate necessary knowledge. To initialize knowledge, the expository presentation of examples establishes a clear case of the content. This is especially important in the learning of complex rules and principles. Instructional strategies of drill and practice help the learner in acquiring the awareness of specific information with an expository presentation (e.g., a lecture) clarifying the understanding. The conventional computer-based enhancements provide for the optimal pacing and display of information while the intelligent enhancements keep the student directly involved with understanding the information to be learned. For example, the mixed-initiative variable allows the student to ask the system a question. Advisement keeps the students informed of their learning progress and needs.

Tracing procedural knowledge. Procedural knowledge is "knowing how." For example, the student knows how to use the APA Publication Manual in the writing of scientific text. The learning objective refers to this process as an intellectual skill, in which the students learn how to employ concepts, rules and principles. The KB here identifies the organizational structure of a given schema. For example, the student knows how to use the heuristics necessary to conduct experiments in educational research. The organization of a schema can take many forms, for example an algorithm or strategy used in searching through a data-based retrieval system.

The primary instructional variables at this level focus on practice of the information in problem or interrogatory situations. Examples should be selected to provide a wide range of applications. Divergent examples allow the students to elaborate on their KB. Tutorial instructional strategies provide a convenient method of interaction between the student and the tutor, be it either a human peer tutor or a computer-based tutor. The basic format is question/answer with the tutor challenging the student to clearly employ knowledge to prevent or eliminate misconceptions.

It is with this instructional strategy that the most dramatic advancements in computer-based instruction have been made in the last ten years. The variables listed in Table 1, are all part my research program the MAIS (Minnesota Adaptive Instructional System). The MAIS is a complete intelligent instructional system with an expert tutor monitoring student learning at all levels of learning. Variables monitored by the MAIS include the amount of information, learning time, sequence of information, feedback, and corrective error analysis. In fact, the MAIS implements all of the enhancements listed in Table 1. Additionally, all of the enhancements have been empirically tested in both laboratory and applied environments.

<u>Tracing conceptual knowledge</u>. This learning process refers to the acquisition of the knowledge of "when and why." For example, the student knows the value of knowing different types of reading strategies. The learning objective, conditional information, implies the ability to perceive the criteria, values, and/or appropriateness for employing concepts, rules and principles. The KB represents an analysis of the schematic network associations and the rules which governor the connections. Knowledge in a KB is represented in a variety of ways. For purposes of education, it is often possible to represent this information in a number forms: for example, a taxonomy, a category, or a hierarchy. The KB here is structured to represent how the knowledge may be organized in memory. Of importance to the KB is the identification of criteria associated with the structure. For example, the learning objective suggests that the student needs to know the conditions of employment as well as the how of employment.

The instructional variables for this learning process influence student learning in two ways: First, they provide an opportunity for the students to experience the KB; and second, they allow t e students an opportunity to develop criteria, values, and appropriateness. Very often these variables are used in all of the identified instructional strategies. The variables of context and advance organizer improve the initial awareness of what is to be learned by helping the student to select and organize appropriate existing knowledge. For example, selecting a specific method or strategy for organizing resourc's to study. Feedback and strategy information improve the integration of the new knowledge into the KB.

Cooperative learning group techniques improve conceptual knowledge acquisition by allowing students to both develop solutions and see alternative solutions to problem situations. Within heterogeneous groups, the students work towards a specific goal by using their respective abilities and aptitudes and, by doing so, improve their understanding of the criteria, values, and appropriateness of knowing when and why to employ knowledge. The task-oriented simulation allows students to work on situations that replicate the employment of the knowledge they are acquiring. Such employment requires them to make decisions on knowledge selection and organization and, by working in a group, see how their ideas relate to the others. Computer-based simulations can provide ease in adjusting the variables and conditions of situations as well as delivering the simulation.

<u>Tracing retrieval skills</u>. Most often cognitive theories of learning focus on knowledge acquisition while basically ignoring employment of knowledge in the service of thinking (i.e., recall, problem solving, and creativity). However, the main goal of education is not acquisition of knowledge, but the improved skill in using it. The traditional schooling paradigm of learning information to develop a disciplined work ethnic only indirectly helped students improve their skills in thinking. Contemporary cognitive psychology that deals with retrieval system theory indicates that thinking skills develop most adequately when working concurrently with the KB. That is, thinking skills in recall, problem solving, and creativity are developed not as general strategies but as specific forms of knowledge embedded in the schemata. And, as skills, the thinking processes of differentiation, integration and creation can be developed and improved. Therefore, such skill development should be an integral part of the instructional system.

For example, my general recommendations for learning time allocation in a curriculum plan for each learning process is as follows: declarative knowledge, 10%; procedural knowledge, 20%; conceptual knowledge, 30%; and thinking skill, 40%. That is, rather than using almost 100% of the instructional time for the learning objectives of knowledge acquisition, a major part of the time needs to be allocated to thinking skill development and improvement. The shift from the traditional schooling paradigm of focus on knowledge acquisition to increased emphasis on thinking skill development puts learning responsibility, or power, more in the hands of the student. This is accomplished by instructional strategies that employ problem-oriented simulations within cooperative learning group techniques.

Problem-oriented simulations (Tennyson, Thurlow, & Breuer, in press) present meaningful and complex problem situations in which students are required to make solution proposals using knowledge stored in memory. The basic format of the simulation is to group students according to similarity of cognitive complexity (i.e., their general skills in differentiation and integration). Within the group, each student is to prepare a proposal individually and then present it to the group. At this point, the student is to advocate his/her proposal. Because of the conflict in this format, each student sees increasingly sophisticated alternatives to the situation which helps them both develop thinking skills and to elaborate and extend their schemata. Additionally, as the simulated variables and conditions change, the students are faced with situations that require them to create knowledge to make proposals. The computer-based enhancements include both the conventional methods of simulation variables and conditions adjustments as well as intelligent methods of monitoring the progress and needs of each student.

Summary

In this article I have presented a means by which educators can determine if specific media variables and methods may improve learning. Thus, I did not attempt to debate whether or not media improves learning. Media is but one component in a complex instructional system. A system that involves principles of instructional design as well as methods of instructional delivery. What I have shown here is that to assume that given instructional methods improve learning, those methods must have two aspects. First, they must exhibit a direct trace to a specific learning process. And, second, they must have empirical support that demonstrates their significance.

Because of the focus of this symposium on the programmatic research of the presenters, I have basically limited my example of the tracing process to my research findings. That of course limits the generalization of the answer to the question on the effect of media on learning, but I am sure others who have done basic research in instructional technology could make a similar effort. By doing so, there would be additional support for understanding the role of media in improving learning.

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