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ABSTRACT

As a means of providing suggestions for improving the quality of the courseware used in computer based education (CBE), this report reviews and evaluates current thought and research on the origins, characteristics, and effectiveness of existing approaches to courseware design. After a brief summary of some of the general problems encountered in courseware design, instructional strategies based upon the structure of knowledge, levels of learning, learner differences, and questioning techniques are outlined and the implications of each type of strategy for courseware development are discussed. A summary of trends indicated by the literature concludes the report, and a 37-item reference list is attached. (JL)

TAXONOMY OF INSTRUCTIONAL STRATEGIES FOR COMPUTER BASED EDUCATION

by

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> . . . most students can attain a high level of learning capability if instruction is approached sensitively and systematically, if students are helped when and where they have learning difficulties, if they are given sufficient time to achieve mastery, and if there is clear criterion of what constitutes mastery.
>
> (Bloom 1976, p. 4)

Perhaps some of the most powerful suggestions for improving the quality of CBE courseware can be derived from observing the origins and characteristics of existing courseware. Historically, when involvement in CBE was restricted to a few (maybe 12) centers across the country, considerable improvement in the quality of courseware could be observed over time as the developers became more experienced and as knowledge of the characteristics of effective courseware began to accumulate and impact new courseware development. However, courseware development is now the purview of anyone with a microcomputer - many of whom are ill prepared to develop quality materials.

Teachers and "computerists" are frequently the authors of CBE courseware. Teachers primarily focus on the act of teaching and the role of the teacher in the process. Typically their experience includes "explaining" and "telling" 20 students simultaneously. When discussing questions of instructional strategy and design, their most common utterance is "I could . . ." Their resulting courseware can often be characterized as an on-line lecture which the student observes.

Computerists whose focus is on "computer power" are generally experienced programmers with educational experience as students and perhaps as the parent of students. In discussing CBE courseware they can be identified by their common utterance "The computer could . . ." The computerist's courseware is characterized by sophisticated pyrotechnics which the student observes.

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The teacher produces courseware which flows from the teacher, through the computer (with little alteration) to the learner. Input, processing, and output are concepts of little consequence. In contrast, the computerist's courseware places heavy emphasis on the processing done by the computer and acknowledges that the computer provides output to the learner and receives input from the learner - generally in the form of a single key press to signal the computer to proceed.

Although the authors' perspectives are subtle and sometimes un-noticed, the impact on the quality of courseware is dramatic. Research has consistently shown that deep cognitive processing by the learner is prerequisite for learning. Deep cognitive processing does not necessarily take place (although it might for some individuals) while the learner 'watches' a program execute on a computer. Rather, asking questions which cause the learner to manipulate content material in ways which he has not been directly taught is a more reliable method of causing deep cognitive processing. Questions which cause the learner to perform at successively higher and higher levels of cognitive activity are the hallmark of quality CBE materials.

At the outset it was hypothesized that effective instructional strategies should consider the structure of the content to be learned, the level of learning desired, and individual differences among learners. Our research, however, has cast doubt on the use of individual differences as a key element in instructional strategies; but rather the kinds of questions presented to learners are an extremely critical variable to be included.

STRUCTURE OF KNOWLEDGE

Almost all words that convey meaning are used as concepts. Whether we are teaching the most basic facts associated with a given content area or the most complex theoretical constructs we are usually teaching concepts. Of particular importance to instruction is the role ascribed to concepts by Klausmeier and Associates (1979):

> Concepts as mental constructs are the critical components of a maturing individual's continuously changing, enlarging cognitive structure and are the basic tools of thought.
>
> (p. 7)

Two alternative approaches may prove useful for instructional development: (1) learning concepts by attribute isolation and identification (Bourne, 1974; Bruner, Goodnow, & Austin, 1956; Haygood & Bourne, 1965) and (2) learning concepts by prototype (clear case or best example) (Garner, 1970; Reed, 1972; Shepp, 1978, Wilson, 1963). The use of one approach or the other, or perhaps a combination of the two approaches, may be greatly influenced by the degree of specificity of concepts in the discipline. Some disciplines may lend themselves very readily to attribute isolation (e.g., mathematics and science) and other disciplines (e.g., social studies and the humanities) may be more amenable to describing examples.

Concept Learning By Prototype

Wilson (1963) proposed that the following elements should be presented sequentially until the learner has grasped the concept: the central meaning, a model case, contrary case, related case, borderline case, invented case, social context, underlying anxiety, practical results, and results in the language.

The prototype (analytic philosophy) approach may be particularly useful for social studies and the humanities because of the abstract concepts and the accompanying lack of specific definition found in those areas. This approach might also be useful as learners mature and advance their understanding to higher levels of abstraction, e.g., as the meaning of "freedom" is refined and expanded from the age of 6 to the age of 15.

Concept Learning By Attribute Isolation

Teaching concepts by attribute isolation is supported by data from a number of researchers (Clark, 1971; Entwistle, 1978; Gagne, 1962; Klausmeier, Ghatala, & Frayer, 1974; Tennyson, Tennyson, & Rothen, 1980; Tennyson, 1980; Tennyson, 1981; Tennyson & Park, 1980; and Tennyson & Rothen, 1979). The procedure usually includes presentation of the concept definition (attributes), an expository presentation of instances of the concept with help in isolating attributes, an inquisitory presentation of instances followed by attribute isolation feedback.

Implications for Courseware Development

Concept learning by prototype and by attribute isolation have been documented experimentally as effective techniques, although much of the data was gathered in classroom and experimental environments which did not incorporate individually adaptive instructional strategies. On the other hand, much existing, adaptive CBE courseware has not incorporated the empirically validated strategies of concept learning. Adapting the experimental findings of concept learning to the adaptive environment of CBE should provide a quantum leap in the quality of CBE courseware.

LEVELS OF LEARNING

Each time a decison is made to provide instruction to a learner, an accompanying decision of level-of-learning should be made. Several taxonomies of instructioal objectives have been developed, but Bloom's

Taxonomy of Educational Objectives was selected because it exhibited the following characteristics: (1) validated comunicability, usefulness, and suggestiveness, (2) emphasis on types of learning tasks generally encountered in instructional environments, (3) broadly accepted by educators, (4) quality documentation, and (5) congruence with the structure of knowledge and the tasks learners are expected to perform within the structure of knowledge.

Implications for Courseware Development

Bloom's taxonomy will provide three important functions for courseware improvement: (1) establish a standard range of levels-of-learning (objectives), (2) raise authors' consciousness of the range of instructional objectives and the improved quality of courseware when higher levels are included, and (3) provide course authoring prescriptions to produce courseware which will cause learners to perform at each level.

LEARNER DIFFERENCES

> . . . Historical emphasis on individual differences has obscured efforts to deal with the educational problems that are more concerned with the quality of interactions between individuals and their educational/social environments.
>
> (Bloom, 1976)

Theoretically, students with high or low verbal, mathematical, spatial reasoning, or mechanical comprehension abilities should react differentially to alternative instructional treatments in the context of specific content. However, Cronbach and Snow (1977) found that special abilities generally do not interact with treatment, whereas general ability is much more likely to do so. Snow (1977) noted that ATI results to date do not make instructional theory impossible, but may make general instructional theory impossible, i.e., instructional treatments applied in a specific setting and at a specific time with a specific student or group of students, may be effective but the same instructional treatments may not generalize to all settings, students, instructors, and times (Snow 1977).

Most educators would agree that learning is a highly complex process that is affected by a number of interacting variables. Individual variables with sufficient power to enable us to design instructional materials around them have not been identified. We do know though that learning is affected by a number of variables including prior knowledge, age, intelligence, social experience and competence, creativity, and motivation. Traditionally, adjustments for these variables have been made at the curriculum development stage to insure that learners and instructional expectations are within a suitable range. Once instruction is started, little attention is paid to systematically adapting to learner differences.

Research to date has not enabled us to knowingly devise instructional strategies to match unique characteristics of individual learners. The research leads to the following postulates for designing instructonal strategies:

-Developmental stages are more related to curriculum development than to instructional development and do not require close attention if authors of CBE courseware are experienced in working with the targeted audience.

-The ability of learners to adapt to instructional environments is more powerful than differential instructional strategies.

-An adaptive instructional strategy which makes 'real-time' adjustments to the demonstrated performance of each learner has in effect dealt appropriately with the individual differences of learners without the need to categorize or label those differences.

QUESTIONING TECHNIQUES

. . . The question is perhaps the primary tool by which the individual processes information regardless of the diversity of his procedure.

(Hunkins 1976, p.4)

The role of questioning in instruction has been a significant concern among educators for well over a half-century. Piaget and Dewey (Newton, 1978) proposed intellectual development through questioning, and over the years educators have advocated the use of effective questions to stimulate thinking among learners (Burton, 1929; Hunkins, 1968; and Taba, 1967). Despite the continuing interest, Gall (1970) concluded that in the last fifty years there has been no essential change in the types of questions teachers emphasize in the classroom. About 60% of teachers' questions require students to recall facts, 20% require students to think, and the remaining 20% are procedural. So much focus has been on the characteristics of questioning practices that little is known about student behavior caused by different types of questions (Buggey, 1972; Dunkin & Biddle, 1974; Hunkins, 1972; Rosenshine, 1971; Ryan, 1973; Savage, 1972; and Tyler, 1972).

Even though only 20% of the questions asked in the classroom require the learner to think (Gall, 1970), many persons believe that a major purpose of education is to help learners develop creative and critical thinking abilities. Watson and Glaser (1964) defined critical thinking as the composite of attitudes of inquiry; knowledge of inferences, abstractions, and generalizations; and skills in applying the above. Dressel and Mayhew (1954) identified five abilities related to critical thinking, ranging from the ability to (1) define a problem (analysis), (2) draw valid conclusions (synthesis), and (3) judge the validity of inferences (evaluation). Questioning learners (and encouraging learners to question also) appears to be the accepted process for achieving the higher cognitive goals of education. If instructional objectives require learners to perform throughout the range of Bloom's taxonomy, then clearly the instructional environment must provide opportunities (questions) which cause learners to practice appropriate performances.

Ryan (1973) dichotomized questions into low levels (recall category) and high levels, the latter including six categories: process, relationship, application, educated guess, synthesis, and opinion. Ryan found that high level questions were more efficient than low level questions for moving students toward both low and high level understandings because high level questions require learners to recall facts and data, then analyze and synthesize the data before responding to higher level questions. Ryan's work suggests that the level of questions defines the level of learning resulting from the instruction, and therefore questioning should be conducted purposefully and systematically. Andre (1977) provided a link between Ryan and Bloom by defining the behaviors required of the learner at each level of Bloom's taxonomy:

Knowledge--repetition of information in the form it was presented. Questions at this level are often labeled factual questions.

Comprehension--recognition or production of some paraphrase of material presented in instruction.

Application--use of presented information in some new situation. Application could include recognizing new examples of a concept or using a principle in a problem solving situation.

Analysis--decomposing a given situation into its component parts and analyzing their relationships. Analysis typically requires the use of some previously taught scheme to decompose the whole, e.g., the student may be told to analyze a short story.

Synthesis--requires production of some product given appropriate elements, e.g., writing a short story.

Evaluation--requires judgments about the value of information, concepts, or ideas relative to some goal or purpose.

Andre proposed that a taxonomy of questions should include 1. objective classification of questions, 2. objective mechanism by which questions of each type could be constructed, and 3. psychological and instructional validity for each category of questions.

Implications for Courseware Development

If knowledge is produced in response to questions, and new knowledge results from the asking of new questions (Postman and Weingartner, 1969), the ability to form concepts and the ability to formulate and respond to questions are related.

CONCLUSIONS

The review of literature has modified and reinforced some of our earlier conjectures on a taxonomy of instructional strategies. The usefulness of a collection of mutually exclusive strategies for describing courseware now seems to be a moot point. Certainly there are broad identifiable strategies such as computer managed instruction, interactive instruction (which generally includes drill and practice and tutorial instruction), and instructional simulations. But these strategies do not describe characteristics of the courseware which are central to the questions of instructional quality we should be asking about courseware -- (1) level of learning provided (rote memory, concept attainment, or concept production), (2) structure of the content, or (3) the level of cognitive processing required of the learner.

A preponderance of literature suggests that most learning is conceptual, and that differing levels of conceptual learning can be defined across the hierarchy of instructional objectives defined by Bloom's taxonomy. Two approaches to teaching concepts have emerged from the literature: (1) prototype presentation and clarification which may lend itself well to the arts, humanities, and social studies where concepts and their attributes are not always clearly defined and (2) attribute isolation and discrimination which may lend itself well to highly structured fields such as mathematics and science. Providing both approaches will accomodate authors from a variety of backgrounds.

Regardless of the approach selected by a courseware author, probably the single most important factor in producing courseware of a high educational quality is the nature of questions which are presented to the learner. The taxonomy must incorporate a taxonomy of question types which cause learners to respond throughout the range of Bloom's taxonomy.

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