Research, Instructional Design, and New Technology

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Research provides valuable guidance for formulating instruction, but using results can be difficult. Research findings often are obtained under controlled conditions, while instruction usually occurs in less controlled settings. Moreover, research isolates variables, while instruction integrates them. In addition, research often produces discrepant outcomes, apparent and real, that must be resolved in application. For example, studies show that learner control facilitates intrinsic motivation, but can be suboptimal for learning. Yet intrinsically motivated learners tend to achieve more. Finally, there is seldom an exact match between real-world instructional problems and those addressed in research. The amount and kind of practice and feedback used in a given situation involves judgment, even though research has documented their benefits. New technology exacerbates these problems because design formats, issues, and questions emerge that researchers have not yet addressed.

Three instructional designs involving new interactive media are examined in this article. Hypotheses about their learning effects are advanced, based on findings in three areas of research. The designs—adaptations of other information technology applications—were chosen because they tend to utilize interactive media capability fully. The research areas were selected because they address some of the benfits claimed for each design. The analysis was undertaken because there is little research on the designs, and because existing instructional research in other contexts may have something to say about them.

The focus here is on the instructional designs that new technologies *allow*, rather than on the media themselves. Research comparing media often is not generalizable and usually confounds variables (Clark, 1983). Studies of computer-based versus classroom instruction, for example, typically find no performance differences, but time savings for those who were computer taught. However, the time reduction is probably due to individualized instruction, not to computers. Moreover, computer-based lessons take longer to develop and often incorporate instructional strategies promoting efficient learning.

Designs

Early interactive programs were pedestrian. Many videodiscs presented lectures, and microcomputer courseware mimicked much of the electronic "page turning" deplored on larger machines. Teaching strategies were used which were known to be ineffective in other, related media. When microcomputers and videodiscs were used together, even the best instructional designs often failed to integrate their capabilities. One medium would dominate because course developers seldom were familiar with both. Programs appeared with long, linear video episodes and little interactivity, or with a lot of interaction and a few poor-quality video images stuck in. Recently more imaginative designs have emerged showing how linking microcomputers and videodiscs makes possible learning environments that are more than the sum of their parts. These designs can be applied to other information technologies such as interactive and read-only compact disks. The designs can be categorized as scenario-based, hypermedia, and parallel systems.

Scenario-based Designs

These designs expose learners to scenarios that are the basis for more didactic instruction. The scenarios are realistic or fantasy "worlds" of video and graphic images. Learners usually are given a goal and must perform tasks to achieve it. A range of tasks and decision options is provided; performance while interacting is monitored in the background. Remedial instruction is given either at the end of the scenario, if the goal is not attained, or during interaction, if too many errors are made. The interface makes interaction easy, often through the use of touch screens, voice recognition units, or other input devices.

There is a series of videodisc emergency medicine simulations that exemplify scenario-based instruction. These programs are used on special workstations having microcomputers, videodisc players, and touch-screen monitors. Physicians view different video episodes of a patient whose condition changes over time. They gather information and prescribe therapies by touching selections on the screen. When the simulations end, physicians can repeat them, see an explanation, compare their decisions to those of experts, view highly structured lessons explaining the condition portrayed, or access references (Allen, 1986). Another example is the army's STARS program (Reeves, Aggen, & Held, 1982) in which soldiers play a video game where they have to travel back in time to give General Patton a message. To attain this goal, they must perform tasks that require using basic skills. They are automatically branched to remedial lessons when errors are made. Lessons must be completed successfully to resume play. The game is, in fact, an invisible diagnostic test with adjunct instruction.

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Hypermedia Designs

These designs provide learners with knowledge bases and related retrieval tools. Original information sources are on-line, not just references. These sources may be textual, graphic, pictorial, or some combination. Each display in the knowledge base functions as a "menu" to other displays and contains cues to additional information available. Learners use these menus to move and manipulate information displays, mark information for later retrieval, reference personal notes, or search related topics. Movement can be both within and among different knowledge bases. Hypermedia programs have been proposed where documents and images could be copied and modified to encourage joint authorship. Trails kept on these transfers would show the evolution of ideas and enable royalty payments (Nelson, 1983).

An example of a hypermedia design is an electronic textbook on pathology (Thursh & Mabry, 1980). Highlighted terms indicate availability of additional text or images. Pop-up menus are evoked by positioning the cursor on terms. Learners can choose to view images on videodisc, see definitions, or search for the term or related topics in the text. The idea is eventually to have an electronic bookshelf so that learners studying the pathology text might instantly jump to anatomy and other textbooks for related information. A second example is an experimental program teaching pushcart assembly (Stone & Hutson, 1984). The initial menu is simply a graphic of the entire cart. Positioning the cursor on any part of the cart causes other displays of assembly diagrams and/or written directions to appear. A third example is a visual data base in histology (Bridgman, Telford, & Allen, 1985). Bar codes are embedded in a hardcopy textbook so its pages can become menus to other information. A bar code reading wand on a small computer is used to call up related videodisc images that augment the text. A visual data base with a different interface overlays icons on video images. Learners use a mouse to select icons that let them see pictures at greater magnification or from different angles (Wertheim, 1986).

Parallel System Designs

These designs involve constructing complementary teaching and testing programs around a common knowledge base. The knowledge base can be accessed in multiple modes, such as information, instruction, or test. For example, in information mode, text and visuals are browsed or retrieved. In instruction mode, additional predesigned information and teaching strategies are provided. In the test mode, questions about knowledge base content are presented. The knowledge base, instructional strategies, and test questions reside "alongside" each other. They exist as separate computer files, but are cross indexed so users can shift between modes any time. One user might start exploring a topic in information mode, decide to be tested on it, and, depending on results, opt for instruction. Another might choose to be tested on the entire knowledge base, and then review only certain topics by accessing information or being taught.

To the authors' knowledge, systems that have been designed intentionally for use in either "tell me," "teach me," or "test me" modes do not exist. One existing system, however, has some of these features. AI/Rheum is an expert system that diagnoses rheumatic diseases. Physicians and medical students can submit data for a new case or choose a case from the system's library. The system renders multiple diagnoses or indicates that it lacks sufficient information. Findings supporting each diagnosis are displayed; additional information needed to confirm the primary diagnosis or an alternative is indicated. Users can ask the system to display the rules used to reach a decision or show and tell them more about diseases and clinical findings. Additional text or videodisc images are displayed in response to these requests (Kingsland, Lindbergh, & Sharp, 1986). Moreover, a complementary system, AI/Learn, is being developed that uses the expert system's videodisc images and decision rules to teach sign and symptom recognition and clinical reasoning.

Research

At least three advantages for using these designs have been advanced. One is that the designs are more motivating—they engage learners and make content more interesting. Another is that the designs may be more suitable for those who have difficulty learning by more traditional methods. A third is that the designs have the ability to give individuals more control of the learning process. Research on intrinsic motivation, aptitude for learning, and learner control of instruction can clarify the validity of these claims.

Intrinsic Motivation

Lepper and Malone (in press) identified three motivation inducers in their research review of intrinsic motivation. Each reflects a different research tradition and view of human nature. The inducers involve providing activities that are neither too easy nor too difficult, that are novel (neither too foreign nor too familiar), and that give some control and self-determination. The first, which considers humans to be problem solvers, is based on research on challenge and feelings of accomplishment. The second, which considers humans to be information processors, is based on research about curiosity and discrepancy coping. The third, which considers humans to be voluntary actors, is based on research about locus of control and feelings of efficacy.

A fourth inducer was not described specifically, but might be inferred from Lepper and Malone's extensive analysis of effective computer game features and the examples they present. This inducer would be to evoke a playful "set," since the games encourage interaction in a nonthreatening context and provide performance feedback. These designs might assume humans to be activity seekers who try to identify personally with their environments.

Aptitude for Learning

Snow and Lohman (1984) identify twelve major findings in their research review on aptitude for learning, three of which are pertinent to the three instructional designs. First, high-ability learners can perform assembly and control functions for organizing activities and guiding learning that low-ability learners cannot. Second, high-ability learners tend to perform better when the instruction provided is incomplete and not prescribed precisely. Since their assembly and control functions are not only more refined but also more idiosyncratic, they adopt highly individualized learning strategies based on their own unique knowledge, background, and experience. Third, providing training and support in self-learning strategies can aid low-ability learners but may not help those of high ability, since high-ability learners' finely tuned learning techniques might be replaced with ones that are less personally optimal. Snow and Lohman warn that teaching strategies that are mathemagenic (giving birth to learning) for some can be mathemathanic (giving death to learning) for others.

Ideally, instructional treatments should vary in completeness and teaching support, and low-ability learners should be taught self-learning skills. Ironically, both high- and low-ability learners tend not to enjoy the teaching strategies that are most effective for them (Clark, 1982).

Learner Control of Instruction

Tennyson and his colleagues (Tennyson, Christensen, & Park, 1984) identify conditions where learner control of instruction may be effective. They have compared performance in learner-controlled and adaptive teaching programs where instructional events change dynamically based on a learner's performance history. For example, the number of practice exercises might vary for each learner when an algorithm using Bayesian statistics is employed to monitor performance and determine whether additional instruction is required.

Adaptive programs are superior to those giving learners total control. However, adding advice improves performance in both programs. Moreover, providing advice in a learner-controlled program can be more efficient than using an adaptive program without advice. Subsequent learner control studies indicate that when learners are given advice, they tend to take it (Hannafin & Colamaio, 1986). If this advice is to adopt the same instructional strategy used in an adaptive or teacher-controlled program, research treatment differences are eroded. However, the effects of advice on experiment integrity are less disturbing than Snow and Lohman's suggestion that advice may have deleterious consequences for high-ability learners.

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Implications

Each area of research provides varying degrees of support for the instructional designs, both individually and collectively. The research suggests when the designs might be used most appropriately with different learners.

- Research on intrinsic motivation would tend to support each approach because they all provide environments that are novel, challenging, self-directed, and sometimes playful. However, if the scenario, hypermedia, and parallel system environments are so complicated that learners lack the requisite knowledge and skill to interact effectively, they could become demotivating. Scenario-based instruction offering remediation when performance is poor might avoid this problem. Unless learners are carefully matched to the instruction on the basis of their existing knowledge and skill, demotivation remains a potential problem for each design.

- Aptitude for learning research also supports each design, but only for sophisticated learners. Most of the designs are open, incomplete, and allow use of idiosyncratic learning tactics.

Hypermedia environments provide little or no teaching support other than the content presented; neither do parallel systems when used in information mode. Moreover, the teaching and testing options they make available are used only at the learner's discretion. Low-ability learners might profit from scenario-based instruction that is highly remedial, and might benefit from the other designs if given training in self-learning skills and in how to manipulate the learning environments effectively.

- Research on learner control of instruction provides only moderate, conditional support for each approach. The research favors scenario-based instructional designs that are highly remedial. It might favor parallel systems because they offer alternative modes of interaction, but only if the designs incorporate means of advising learners when to use each mode. The research would only support hypermedia and more open scenario-based designs if they also offered learning advice. Whether adaptive, advice-giving strategies are recommended for both high- and low-ability learners is unclear.

These conclusions only apply to the designs as they are presently conceived and implemented. Modifications might rectify their deficiencies. For example, scenario-based instruction might be devised that provides not only remediation, but also advice, and that adjusts the complexity of a situation a learner encounters. Parallel systems might have both sophisticated and simplified explanations of content in their knowledge bases, as well as multiple teaching strategies. They could advise learners about which explanations and teaching strategies to use. Similar features might be built into hypermedia programs. These adjustments and enhancements might ensure successful interaction and learner motivation, and make the designs more appropriate when self-learning skills are lacking. Perhaps the amount of additional support provided could be adjusted according to learner sophistication. On the other hand, such modifications may be unnecessary or undesirable for high-ability learners.

Conclusion

The instructional designs described have the following common characteristics: they are information rich; they provide unprecedented amounts of learner control over what content will be learned and the sequence and pace of instruction; and the control is highly virtual, with the technology responding almost immediately to learner requests. If these designs are indicative of others that might be realized, then the new information technologies make possible more open instructional environments that are intrinsically motivating and effective for some. Sophisticated learners might benefit more from these designs than from more structured ones, but these are the same learners that do well in contemporary instruction and who manage to succeed regardless of the approach. The designs are not for everyone, but might be altered so they can be used effectively by less able learners. Moreover, if these designs become increasingly incorporated into the general information technologies people encounter in everyday life, they underscore the need to teach people better self-learning skills.

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