The Influence of Media on Learning: The Debate Continues

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Do media influence learning? Perhaps it is time to rephrase the question: *How*, do media affect learning? Perhaps it is time to go beyond our concern with "proving" that media "cause" learning so that we can begin to explore the question in more complex ways. Perhaps we should ask, what are the actual and potential relationships between media and learning? Can we describe and understand those relationships? And can we *create* a strong and compelling influence of media on learning through improved theories, research, and instructional designs?

There is a certain urgency about this question. In the near future, telephone, cable television, and digital computer technologies will merge,(5) presenting the prospect of interactive video integrated with large multimedia databases to be distributed to people in various settings all over the world. If we do not soon understand the relationship between media and learning—if we have not *forged* such a relationship this technology may be used primarily for interactive soap operas and online purchases of merchandise. Its educational uses may be driven primarily by benevolent movie moguls who design "edutainment" products whose contribution to learning may be minimal.

In order to understand the actual and potential relationships between media and learning, we must first understand why we have thus far failed to establish a causal connection. In large part, this failure is due to the fact that our theories, research, and designs have been constrained by vestiges of the behavioral roots of instructional technology.(6) Both traditional instructional design models and comparative media studies rest on the assumptions of the behaviorist paradigm: media "stimuli" are described according to the surface features of their technologies, and their effect on learning is assessed by using "responses" on a test. Missing from this approach are any descriptions of the cognitive, affective, or social processes by which learning occurs. Also missing are descriptions of the underlying structures and functions of various media that influence these processes. Clark's delivery truck is an apt metaphor for this approach. The medium itself is only an inert conveyer of an active stimulus to which the learner makes a behavioral response.

But today we understand that learning is not simply a passive response to instruction's "delivery." Rather, learning is an active, constructive, cognitive, and social process by which the learner strategically manages available cognitive, physical, and social resources to create new knowledge by interacting with information in the environment and integrating it with information stored in memory.(7) From this perspective, knowledge and learning are the result of a reciprocal interaction between the learner's cognitive resources and aspects of the external environment.(8) Moreover, this interaction is strongly influenced by the extent to which internal and external resources fit together.(9)

Consequently, to understand the role of media in learning, we must fundamentally change our traditional approach to this issue:

- We must ground a theory of media in the cognitive and social processes by which knowledge is constructed.
- We must define media in ways that are compatible and complementary with these processes.
- We must conduct research on the mechanisms by which characteristics of media might interact with and influence these processes.
- We must design our instruction in ways that embed the use of media in these processes.

A New Look at the Question

Early attempts to review research findings in light of the new assumptions noted above suggest that “learning with media [is] a complementary process within which representations are constructed and procedures performed, sometimes by the learner and sometimes by the medium.” Media embody certain characteristics that “interact with learner and task characteristics to influence the . . . structure, formation, and modification of mental models.”(10) Within this framework, particular media formats (e.g., books and magazines, video media, computer software, and multimedia) possess particular characteristics that make them both more and less suitable for the accomplishment of certain kinds of learning tasks.

Gavriel Salomon argued that media can be analyzed in terms of their “cognitively relevant” capabilities—i.e., in terms of those characteristics that affect the ways in which individuals represent and process information.(11) These capabilities relate to three aspects of each medium: its technology, symbol system(s), and processing capabilities. “Technology” refers to the physical, mechanical, or electronic capabilities that determine a medium’s function. “Symbol systems” are sets of symbolic expressions by which information is communicated(12) according to specific rules and conventions: spoken language, printed text, pictures, numbers, graphs, and musical scores exemplify symbol systems. “Processing capabilities” refer to a medium’s abilities to operate on symbol systems in specified ways-for example, by displaying, receiving, storing, retrieving, organizing, transforming, or evaluating whatever information is available through a particular symbol system.

Each medium can be defined and distinguished from others by a profile of these three kinds of capabilities. Using this profile, a particular medium can be described in terms of how it presents certain representations and performs certain operations in interaction with learners—who are simultaneously constructing and operating on mental representations. From this perspective, then, learning with media is a complementary process within which a learner and a medium interact to expand or refine the learner’s mental model of a particular phenomenon. The question then becomes not do media enhance learning but how, do the capabilities of a particular medium facilitate particular kinds of learning?

Learning with Books

The most common medium encountered in school learning is still the book. As a learning medium, the book can be characterized by the primary feature of its technology (that is, stability), by its symbol systems (printed text, pictures, and graphics), and by the way it influences specific processes (reading).

The primary symbol system used in books and other print media consists of orthographic symbols that, in Western culture, are words composed of phonemic graphemes, horizontally arrayed from left to fight. In most printed school media, this arrangement is stable—unlike the marquee in Times Square, for example, which uses the same symbol system but a different and transient technology. The stability of the medium has important implications for how learners process information from books and magazines: it aids in constructing meaning from the text.

In general, reading progresses in a forward direction and at a regular rate as the reader moves along, readily constructing a mental representation that relates the information in the text to an existing mental model. But on occasion, reading processes interact with prior knowledge and skill in a way that relies heavily on the stability of text to aid comprehension and learning. While poor readers are often thwarted by the effort required to decode the text,(13) fluent readers use the stability of the text to avoid reading failure: encountering longer or novel words, these readers will slow their rate, go back to review a word as an aid to recalling a meaning for it, or review a phrase or sentence to determine the meaning of the word from context.(14) Even readers with highly developed reading skills and elaborate memory structures rely on the stable structure of print to process large amounts of text in familiar domains: a study by Charles Bazerman, for example, revealed a strategy by which seven physicists read selectively and for a particular purpose by scanning print rapidly and using certain words to trigger decisions either to skip over familiar information or to move back and forth carefully within a text and across texts to add to their understanding of their field.(15) Most readers, then, use the stability (technology) of the printed text to process (read) its content (symbol system) and thereby construct or elaborate on a mental model.

What happens when pictures or diagrams are introduced into this medium? What is the cognitive effect of these symbol systems in combination with text? And how does the stability of these symbols, as presented in books, interact with processing? A large body of traditional research suggests that using pictures in combination with text generally increases recall, particularly for poor readers, if the pictures illustrate information central to the text, when they represent new content that is important to the overall message, or when they depict structural relationships mentioned in the text.(16) Analyzing this research according to the perspective of this column suggests that the use of both symbol systems in a stable medium facilitates a particular kind of processing, particularly for learners who have little prior knowledge of the topic.

Several studies indicate that readers use pictures to create or to evoke preliminary mental models that guide subsequent reading and assist in the construction of more elaborate and interrelated models.(17) Other studies suggest that the use and effectiveness of pictures are related to prior knowledge: more knowledgeable readers tend to build mental models from existing knowledge and to elaborate on them using information from the text, while less knowledgeable readers tend to rely more heavily on pictures or diagrams to construct mental representations of new information.(18) Younger children, who may not have sufficient prior knowledge from which to generate elaborate mental models, may benefit most from pictures to aid this process.(19)The stability of the medium allows the kind of serial, sequential, back-and forth processing between specific information in the text and components of the pictures that facilitates the construction and elaboration of mental models.

Learning with Television

Television—or any video medium—differs from books in several ways that may affect cognitive structures and processes. First, the technology of these media makes both their verbal and visual symbol systems transient rather than stable. Linguistic information can be orthographic (as in captioned films); but more often it is oral and, like the images on the screen, disappears quickly. Because of this transience, and because the two symbol systems are presented simultaneously—learners may process the information in video media very differently from the way they process similar information in books and magazines. It is also possible that the symbol systems and their transient nature affect the mental representations that learners create.

A number of studies have found that viewers allot their attention to television in various and predictable ways. This research indicates that visual attention increases from very low levels during infancy to a maximum in the late elementary school years,(20) and that the nature of this attention is influenced by several factors. Even though they may appear distracted at times, children continually monitor the audio portion of a television presentation at a superficial level, and their visual attention is triggered by particular audio cues: women's and children's voices, peculiar voices, sound effects, and auditory changes. Features associated with continued visual attention are special visual effects, pans, and high physical activity; visual attention frequently decreases with the use of men's voices, long zooms, and inactivity.(21) These "formal features"(22) come to be seen by children as corresponding to the meaningfulness of the content, and it is this meaningfulness that subsequently guides and maintains visual attention. For example, children's viewing experience may lead them to perceive that men's voices generally correspond to content that is adult-oriented and therefore less interesting and meaningful to them.(23)

Several aspects of video media seem to have particular effects on learners' cognitive mechanisms: the simultaneous presentation of auditory and visual information, the processing pace required by transient presentations of information, and the ways in which dynamic qualities might affect a learner's mental models.

Most studies of the roles of audio and visual presentations show that the combined use of the two symbol systems results in more recall than visual-only and audio-only presentations.(24) Additionally, several studies suggest that each source provides information that retains some of the characteristics of the original symbol system: children recall sounds and expressive language from the audio track and visual details from the visual track.(25) It also appears that the representations derived from the visual symbol systems are more elaborate, making the visual component of the presentation particularly memorable.(26) Audio may be sufficient for those who are knowledgeable about a topic and can draw on previous knowledge for their mental models, but the visual symbol systems supply important situational information for those who are less informed.

An important aspect of video is its transience. Only limited research has addressed the effect of pace on comprehension,(27) but this aspect of video presentations clearly distinguishes them from print and may interact with learning in significant ways. With books, the reader sets his or her own cognitive pace (i.e., words per unit of time) to accommodate personal requirements for comprehension. With video, the pace is set by someone other than the learner, and the presentation (i.e., words or visual elements per unit of time) progresses without regard to individuals' cognitive requirements. Analyzing this situation from the perspective of this article suggests several avenues that researchers might pursue to understand the effect of such pacing on comprehension: because viewers use their prior knowledge to process words and ideas, knowledgeable learners are probably able to process information at the pace it is presented partly because they can use their long-term memories to supplement information they might have missed. If the topic is unfamiliar, however, and little information exists in long-term memory to supplement viewing, the pace may exceed the learner's capacity to process. Further, because the information is transient, a learner cannot regress over it to refresh short-term memory. The cascading comprehension failure that has been documented in such situations(28) might well be explained through research that focuses on these cognitive dimensions.

There is a third aspect of the ways in which video media might affect learning—the ways in which their dynamic qualities interact with a learner's mental models. Understanding this aspect requires some additional information on the nature and uses of mental models. According to various authors,(29) mental models consist of sets of mental entities that are connected by relationships and procedures and can be "run" in ways that have some similarities to the running of a computer program. For example, a mental model of a media center would include information about the roles of the staff, the nature and location of the collection, the rules and Procedures for circulation, and so on; the library media specialist trying to solve a problem-for example, determining how to introduce a new electronic catalog to teachers and students-could "run" this model to make inferences about what would and should happen in such an introduction. "Running the model" would thus help the library media specialist design a solution to the problem at hand.

In this way, mental models are themselves dynamic, since they include mechanisms for moving from one representation of information to another—for example, from a mental model of the library media center without an electronic catalog to one of the library media center with such a resource. Because of this dynamism, the moving, transient nature of video presentations may help learners build the dynamic properties of their mental models. A film about the Battle of Gettysburg, for example, might be especially effective in helping students understand not only specific battlefield conditions but how those conditions changed over the three days of fighting and transformed what might have been a Confederate triumph into a Union victory. By helping the student understand the transformation of information (for example, the state of the battle) from one situation (its state on July 1) to another (its state on July 3), the film might promote the creation of a mental model that includes a sophisticated awareness of this transformation as well as of simple facts.

Again, lack of research in this area means that these contentions are only speculative; they suggest, however, that the technology of video media (dynamic, transient) and their simultaneous presentation of two symbol systems exert a strong influence on learners' mental models and the processes used to construct them.

Learning with Computers

Computers can be distinguished from the two previous formats by what they can do with information—that is, by their ability to process symbols and symbol systems. The prototypic "information processors," computers can transform information in one symbol system to that in another and they can "proceduralize" information.(30) In its transforming function, a computer with a voice synthesizer can change typed text (i.e., print) into speech; using an integrated software package, it can transform numerical values into charts and graphs. In its proceduralizing function, a computer can operate on symbols according to specified rules: for example, it can rotate a graphic object on the screen according to the laws of physics. Through both functions, a computer can help students construct links between symbolic domains—like graphs and equations—and the real-world phenomena they represent. So it is the processing capabilities of the computer, rather than its symbol systems per se, that enable this medium to make its primary contribution to students' construction of their mental models.

Students are frequently unable to connect their symbolic learning in school to "real world" situations,(31) but the transformational capabilities of the computer can help them make this connection. For example, several studies have shown improvement in graph-interpretation ability for students working in microcomputer-based laboratories.(32) These laboratories use sensors connected to a computer to collect data (e.g., on temperature and motion); the computer transforms the data, displaying the information as graphs rather than numbers. The transformation capabilities of the computer thus make immediate and direct the connection between the graphic symbols and the world they represent. Seeing this connection aids in the development of students' ability to read graphs—that is, to transform a graph into a description of what it means in the "real world."

Perhaps even more importantly, the processing capabilities of the computer can help novices build and refine mental models to be more like those of experts. Much of the research in this area has involved physics, in which series of studies have established the nature of experts' knowledge: it is extensive, organized into large chunks that are structured around the laws of physics, and includes information both about the formal laws of physics themselves and about how and under what conditions these laws apply.(33) Novices' knowledge, however, is not only less extensive but is organized differently: it might include only physical objects like blocks and pulleys, fragments rather than interrelated sets of concepts, and "laws" that are incomplete or otherwise incorrect.(34) When trying to solve problems, then, novices often construct mental models that are incomplete, inaccurate, or otherwise insufficient.

How might the processing capabilities of computers be used by novices to aid them in building more expert-like models? First, the computer can graphically represent the formal, abstract entities that novices do not normally include in their models. The computer, for example, can use an arrow to represent "force"—that is, an influence that changes the movement or shape of an object—a construct that has no concrete referent in the physical world. Second, the computer can proceduralize the relationships among these graphic (and other) symbols and display the results of those procedures. It can change the shape or direction of the arrow to represent what actually occurs, according to the laws of physics, when force is increased, decreased, or applied from different directions. Furthermore, the computer allows learners to manipulate these symbols and observe the consequences, successful or unsuccessful, of their decisions. Through a series of such experiences, novices may become aware of the inadequacies of their own mental models and move progressively toward more elaborate, integrated, and accurate ones.(35)

Thus, the processing capabilities of the computer can influence the mental representations and cognitive processes of learners. Their transformation capabilities can connect symbolic expressions (such as graphs) to the actual world. Their proceduralizing capabilities can allow students to manipulate dynamic, symbolic representations of abstract, formal constructs that are frequently missing from their mental models in order to construct more accurate and complete mental representations of complex phenomena.

Learning with Multimedia

Little research has been done on learning with multimedia environments, primarily because the field is still evolving and most efforts within it are focused on development. However, multimedia present the possibility of combining in a single instructional environment all the technologies, symbol systems, and processing capabilities of the individual media described above. Examining how we might use each of these aspects individually and in various combinations to facilitate learning is an important direction for current and future research.

Computer technology plays a central role in multimedia environments: the computer coordinates the use of various symbol systems and processes information it receives, collaborating with the learner to make subsequent selections and decisions. This role is essentially the same whether the specific multimedia format in use is interactive video or hypermedia.

One of the best known examples of the interactive video environment is the “Jasper Woodbury Series,”(36) which provides realistic contexts to help middle-school students learn complex problem solving in mathematics. Each videodisc provides a series of stories about Jasper Woodbury (who is approximately the same age as the target students) that contain both the problems to be solved and data that can be used in the solutions. In one story, for example, Jasper takes a used boat for a “test drive” and decides to buy it. The problem, briefly stated, is that the boat’s running lights do not work and Jasper must determine if he can get the boat to his home dock before sunset. The students are left to solve the problem, using major questions embedded in the story itself: does Jasper have enough time to get home before sunset? enough gas? enough money to buy the necessary gas?

Students work in groups to determine the solution, encouraged by the teacher to generate subordinate questions and to identify the information needed to solve them. They review segments of the videodisc to search for information and to separate relevant from irrelevant facts; use the facts to solve the subordinate problems; and then relate these partial solutions to the overall problem. Early research on the influence of “Jasper Woodbury” on learning is encouraging.(37)

What contribution did the videodisc make to this learning? Several contentions are suggested. First, the capability of the video to use multiple symbol systems to present complex, dynamic social contexts and events might have helped students construct rich, dynamic mental models of the situations. The detailed, dynamic nature of these models might have allowed students to draw more inferences than they could from mental models constructed from text or still pictures.(38) As we have already noted, such structures are more memorable than those constructed with text(39) and rely less on information in students’ heads(40) which is likely to be incomplete or inaccurate for students with limited prior knowledge. The video also preempts demands on reading ability, allowing students who have not yet automated their reading skills to focus their cognitive resources on the problem-solving task.

Second, the videodisc contains a great deal of information crucial to the solution of the problem: information about distances, available money, and other relevant conditions is embedded in objects and maps and in what people say, do, and think as the story is enacted. The random access capabilities of the computer-controlled videodisc allow students to pause, review, and search for information they may have missed or forgotten. Identifying needed information and extricating it from a context is an important component of learning to solve problems, and the ability to do so contributes to successful transfer and performance in actual situations.

Finally, and most important, the visual and social nature of the story, as presented in this environment, is likely to activate relevant prior knowledge that students can use to solve the problem. Further, because of the scope of detail and relationships the environment provides, students are likely to find many ways to connect their new learning to their existing representations. ‘This, in turn, increases the likelihood that similar situations will evoke the appropriate solution procedures in the future. Over time and similar experiences, these learned strategies will become connected to a range of mental representations, promoting transfer of the strategies to a variety of problem situations.(41)

As a distinct type of multimedia, hypermedia shares the technology and symbol systems of interactive video environments but embodies processing capabilities that suggest an important difference for learning. The nonlinearity of hypermedia—that is, the capability of this technology to allow learners to create associational links within and across text, images, and other symbol systems—facilitates cognitive flexibility because it allows a topic to be explored in multiple ways using a number of different concepts and themes.(42) This exploration should result in the development of integrated, flexible knowledge structures interconnected by crisscrossing conceptual themes that facilitate the use of this knowledge to solve a wide range of problems. Each concept can subsequently be used in many different ways, and the same concept can apply to a variety of situations.

Some hypermedia systems allow learners to add their own information and construct their own relationships. As Gavriel Salomon points out, such systems can reflect the processes learners use when constructing interrelationships in their own mental models and thus encourage them to think not only about ideas but about how they are interrelated and structured.(43) More important, such systems can provide explicit models of information representation that learners can use as guidelines for constructing their own internal models.

While there has been only limited research in hypermedia to date, preliminary findings are encouraging.(44) Despite the appeal of hypermedia, however, it is important to note some potential disadvantages for learning as well. In hypermedia environments, users are frequently required to decide what information to select and in what order; building such sequences is likely to be particularly difficult for novices, who lack the extensive and well-organized mental representations that would allow them to locate appropriate information and integrate it with their prior knowledge, experience, and opinions. Getting “lost in hyperspace” and failing to find or recognize relevant information are other potential problems, particularly for novices, as is spending inordinate time and cognitive energy processing information that is not relevant to their purposes.

In summary, the technology of integrated multimedia environments brings together the symbolic and processing capabilities of all the various media described above. Interactive videodisc environments may help learners build and analyze mental models of problem situations, while hypermedia environments may help learners build links across information presented by different symbol systems and construct meaning based on these links. Plausible rationales have been given for the expected effectiveness of such environments, but much more research is needed to understand—let alone forge the relationships that proponents of these environments hypothesize.

Conclusions

How does the analysis above contribute to a theory of learning with media? Richard Clark would say it does not. Attributing media effects to their capabilities, or attributes, invokes his criticism of the media attribute approach.(45) But when we abandon the conception of attributes as single and discrete causal entities and consider that each medium is defined by its particular cluster of capabilities, we are perhaps able to broaden the discussion. Further, when we consider the various ways in which these clusters interact with cognitive processes and structures, perhaps we can refocus the discussion to explore specific ways in which media capabilities may be used to influence learning for individual learners performing particular tasks in specific content areas. Understanding how learners interact with and use the unique capabilities of each medium’s format is essential to understanding the effect of media on learning.

The field of educational technology is reexamining its foundational assumptions and questions.(46) This article is part of my ongoing attempt to contribute to that effort. If we move from “Do media influence learning?” to “In what ways can we use the capabilities of media to influence learning for particular students, tasks, and situations?” we will both advance the development of our field and contribute to the improvement of teaching and learning.

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Note: The first four footnotes are referenced from the introduction to this article by Delia Neuman.

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