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Will Media Influence Learning?

Reframing the Debate

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ABSTRACT

This article addresses the position taken by Clark (1983) that media do not influence learning under any conditions. The article reframes the questions raised by Clark to explore the conditions under which media will influence learning. Specifically, it posits the need to consider the capabilities of media, and the methods that employ them, as they interact with the cognitive and social processes by which knowledge is constructed. This approach is examined within the context of two major media-based projects, one which uses computers and the other video. The article discusses the implications of this approach for media theory, research, and practice.

Do media influence learning? Ten years ago, Richard Clark (1983) reviewed the results of comparative research on educational media and claimed that they provide consistent evidence ". . . for the generalization that there are no learning benefits to be gained from employing any specific medium to deliver instruction" (p. 445). According to Clark, the results of those studies that appear to favor one medium over another are due not to the medium but to the method or content that are introduced along with the medium. Clark concludes that ". . . media do not influence learning under any conditions" (p. 445). Rather, ". . . media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (p. 445).

It is time to revisit this question. Or perhaps, it is time to reframe it. Perhaps the appropriate question is not do but will media influence learning. Educational technology is a design science (Simon, 1981, Glaser, 1976), not a natural science. The phenomena that we study are the products of our own conceptions and devices. If there is no relationship between media and learning it may be because we have not yet made one. If we do not understand the potential relationship between media and learning, quite likely one will not be made. And finally, if we preclude consideration of a relationship in our theory and research by conceptualizing media as "mere vehicles," we are likely to never understand the potential for such a relationship.

There is a certain urgency about this question and a reason to revisit it now. In the not-too-distant future, we will be faced with a situation where telephone, cable television, and digital computer technologies will merge (Information Infrastructure Task Force, 1993; Stix, 1993). This capability presents the prospect of interactive video integrated with access to large multimedia data bases distributed among people in offices, classrooms, and living rooms all over the world. If by then we have not come to understand the relationship between media and learning—if we have not forged a relationship between media and learning—this capability may be used primarily for interactive soap operas and on-line purchasing of merchandise with automatic funds transfer. Its educational uses may be driven primarily by benevolent movie moguls who design edutainment virtual reality adventure games and the contribution of educational technologists will be minimal. Once again, we may find ourselves on the sidelines of our own game (Reigeluth, 1989).

In order to establish a relationship between media and learning we must first understand why we have failed to establish one so far. In large part, the source of this failure is due to the fact that our theories, research, and designs have been constrained by vestiges of the behavioral roots from which our discipline sprang (Richey, 1992; Winn, 1989, 1990). Embedded in the instructional presentations and criterion-referenced tests of our instructional designs (Dick & Carey, 1990) and embedded in the comparative media studies included in Clark's (1983) review are the primal stimuli and responses of the behavioral paradigm. Media "stimuli" are classified and differentiated based on surface features of their technologies and their effect on learning is compared using "responses" on a test. Missing in these studies are any mentalist notions or descriptions of the cognitive, affective, or social processes by which learning occurs. Also missing are descriptions of the underlying structure and functions of media which might serve as the causal mechanisms—or "first principles," to use Winn's (1989) term—that influence these processes. The theoretical frame of reference implicit in these studies—that of presentation and response—is aptly characterized by Clark's delivery truck metaphor: The medium is an inert conveyer of an active stimulus to which the learner makes a behavioral response.

However, as we have come to understand, learning is not the receptive 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 already stored in memory (Shuell, 1988). From this perspective, knowledge and learning are neither solely a property of the individual or of the environment. Rather, they are the reciprocal interaction between the learner's cognitive resources and aspects of the external environment (Greeno, 1988; Pea, 1993; Perkins, 1993; Salomon, 1993) and this interaction is strongly influenced by the extent to which internal and external resources fit together (Snow, 1992).

Consequently, we will understand the potential for a relationship between media and learning when we consider it as an interaction between cognitive processes and characteristics of the environment, so mediated (Salomon, 1993; Salomon, Perkins, &

Globerson, 1991). Specifically, to understand the role of media in learning 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, and we must design our interventions in ways that embed media in these processes.

In this paper, I use the interaction between information and processes in the mind and those in the environment as a framework to examine the potential relationship between learning and media. I analyze the results of two significant and effective instructional environments to identify causal mechanisms by which media may have influenced learning. And I discuss the implications of this approach for a theory of, research on, and practice with educational media.

Successful Interactions in Two Environments

ThinkerTools. Students' understanding of Newtonian mechanics is very different from that of experts. Expert physicists examine problem situations and see patterns based on underlying structure (Chi, Feltovich, & Glaser, 1981; Larkin, 1983). The mental models that they build of these situations include entities that correspond to the physical objects encountered in the problem situation, as well as entities that correspond to the formal constructs of physics that have no direct, concrete referent in the real world (e.g., force vectors). The relationships among these entities correspond to the laws of physics. Experts reason qualitatively with these models to construct and test problem solutions.

On the other hand, the mental models built by novices are composed primarily of entities that correspond to the familiar, visible objects mentioned in the problem statement (e.g., blocks, pulleys, inclined planes, etc.). They do not contain entities that represent formal physical constructs or relationships. Thus, the models that novices form are insufficient to determine a solution to the problem.

White (1984, 1993) developed a computer-based learning environment, called *ThinkerTools*, to address learning difficulties that students have in Newtonian mechanics. The curriculum for this microworld consists of four modules that present progressively sophisticated models of force and motion. Each module incorporates four phases: a motivation phase, a model evolution phase, a formalization phase, and a transfer phase.

In the motivation phase, the teacher describes real world situations involving forces acting upon objects, and students are asked to predict the outcome. The various outcomes are listed on the board without evaluative comment. Motivation is drawn from the conflict among the statements and from the learners' need to master their environment.

In the model evolution phase, students work in pairs to solve problems of the sort presented during the motivation phase and perform experiments using the microworld. On the screen of the computer students see two coordinated representational forms. In one, students are given a dot and a target and asked to "impart a force" on the dot so that it will hit the target at a specified speed. They do this with their joy stick by moving the stick right, left, up, or down to indicate the direction of the force. The second representation is a "data cross" that shows the amount of force imparted as decomposed force vectors, such that an arm of the cross (right, left, up, down) darkens one "unit" for each movement of the joy stick in the corresponding direction (i.e., one movement right and two movements up would darken the right arm of the cross one unit and the up arm two units). Correspondingly, an arrow appears next to the dot pointing in the vectoral direction of the forces; a "flame" emanates from the back of the arrow and a "swooshing" sound is made. The dot moves accordingly and behind it a series of small dots, called a "wake," appear at regular time intervals, spaced so that the faster the object moves the farther apart the dots appear. While conducting these exercises, students are asked to write down what happens.

These model evolution exercises are structured across modules so that the problems and activities become increasingly sophisticated. For example, in the first module students work only with motion in the horizontal (i.e., right and left) directions. In the second module, one student controls the horizontal force and the other student controls the vertical. Together they explored the combined vectoral forces in all four directions to maneuver the dot around a more complicated route to the target. The final model of force and motion includes motion in all directions, continuous motion, and representations of friction and gravity.

During the formalization phase, students must come up with a "law" that describes the behavior of the microworld. With early modules, students are given alternative laws and they must select the ones that best describe their experience. Students work together in small groups (three to five students) with the computer to test the different "laws" and decide which ones are supported by their results. The groups present their decisions to the class and these are debated. In subsequent modules, students must work together to invent their own laws and experiments. Thus, while the models become increasingly difficult, the students also receive less guidance.

During the transfer phase, students apply the laws that they have formulated to answer the predictive questions raised during the motivation phase. This is done by conducting experiments on the computer and with real world objects in the classroom to test the limits and qualifications of their laws.

This environment was used with 42 sixth grade students for their 45 minute science class every day for two months (White, 1993). They were compared to 37 sixth graders in the same school who received the standard science curriculum (a unit on inventions) taught by the same teacher. They were also compared to two groups of 11th and 12th grade high school students in the same school system. One group had just completed 2 1/2 months studying Newtonian mechanics using a commercial textbook and traditional teaching methods; the second group of high school students was at the very beginning of their physics course. All of these students were given tests that required them to predict the outcomes of real world force situations. Both the students who used *ThinkerTools* and the high school students that studied mechanics performed significantly better on the tests than their respective control groups. However, the students using *ThinkerTools* both demonstrated significantly greater improvement and scored significantly higher than the high school students who were on the average six years older, had selected themselves into physics, and had been taught about force and motion using traditional methods.

The *Jasper Woodbury Series*. In schools, students frequently have difficulty drawing on the knowledge that they have of situations in the real world (Resnick, 1987). Conversely, the knowledge of solution strategies that they acquire in school is frequently stored in ways that are not evoked by problem situations that they encounter outside of school. This severely limits the transferability and utility of school-learned knowledge, what is sometimes called the "inert knowledge problem" (Whitehead, 1929).

The Cognition and Technology Group at Vanderbilt University has developed a set of videodisk-based problem situations in mathematics, called the *Jasper Woodbury Series* (Van Haneghan, Barron, Williams, Vye, & Bransford, 1992; Cognition and Technology Group at Vanderbilt, 1992), that addresses this problem. The set provides teachers and middle school students with real-world contexts for learning complex mathematics problem solving. The videodisk is used to provide rich stories which embed both problems to be solved and data which can be used in the solutions. For example, in one story, the principal character, Jasper Woodbury, takes a river trip to examine a used boat, which he decides to buy. The problem, very briefly stated, is that because the running lights do not work, Jasper must determine if he can return to his home dock before sunset. The students are left to solve this problem. There are several major questions that are embedded in Jasper's decision: Does he have enough time to return home before sunset, and is there enough fuel in the boat's gas tank for the return trip? If there is not enough fuel, does Jasper have enough money to buy the necessary gas?

In the classroom, students work in groups with the teacher's guidance to determine the solution. The teacher encourages students to generate subordinate questions and identify relevant information needed to solve these problems. Students review segments of the video to search for information and separate relevant from irrelevant facts. They use the facts to solve the subordinate problems and then relate these solutions to the overall problem.

Students viewing the episode and receiving this instruction were compared to a control group (Van Hanenghan, et al., 1992). This second group of students also viewed the boat episode. However, instead of receiving guidance in solving problems as they related to the problem context, they received instruction and practice in solving problems of the sort that Jasper would have to solve (distance, elapsed time, fuel consumption rate, etc.) but structured as word problems without specific reference to the Jasper story that they saw. In addition, they studied Polya's (1957) general model of strategies used to analyze and solve problems. Students were encouraged to use it to solve their word problems.

So, the difference between the two treatments was this: while both groups viewed problem contexts (i.e., the video story) and studied problem solving skills only the first group explicitly integrated problem solving and context. Students in this group scored significantly higher from pre to post test on questions related to the boat episode; the control group did not. In addition, the experimental group scored as well as the control group on a set of word problems like those that the control group received during practice sessions. Finally, the experimental group scored significantly higher than the control on a different, video-based story problem. The experimental group score a mean of 58% on this transfer task, with several of these students scoring between 75%-100%. The maximum control group score was 51%; their mean was 29%. Of particular significance was the sort of errors that students in the control group made. Some of these students mixed units (e.g., added hours and miles) or confused rates (e.g., minutes per mile and miles per minute) that indicated a lack of meaningfulness in the solution procedures they were attempting. Of those students who gave the correct answers to mathematical problems, few went on to show how these answers solved the overall problem. That is, while some students in the control group were able to acquire certain solution procedures they were unable to apply these to solve real world-like problems.

The Role of Media

What contribution did media make to the learning documented above? To understand this, we must think about media not in terms of their surface features but in terms of their underlying structure and the causal mechanisms by which they might interact with cognitive and social processes. Media can be analyzed in terms of their cognitively relevant capabilities or attributes (Salomon, 1978). These include a medium's technology, symbol systems, and processing capabilities (Kozma, 1991). "Technology" is the physical, mechanical, or electronic capabilities of a medium that determine its function and, to some extent, its shape and other features.[1] These are the surface characteristics of media that we typically use to classify something as a "television," a "radio," and so on, in everyday language. From a theoretical perspective, however, the primary effect of a medium's technology is to enable and constrain the other two capabilities and these are the aspects of media that have more direct implications for cognitive processes. “Symbol systems” are sets of symbolic expressions by which information is communicated about a field of reference (Goodman, 1976). Examples of symbol systems include spoken language, printed text, pictures, numerals and formulae, musical scores, performed music, maps, graphs, and so on. "Processing capabilities" are the ability of a medium to operate on available symbol systems in specified ways. In general, information can be displayed, received, stored, retrieved, organized, translated, transformed, and evaluated among other processes.

Each medium can be defined and distinguished from others by a profile of these capabilities. Using this profile, a particular medium can be described in terms of its capability to present certain representations and perform certain operations in interaction with learners who are similarly engaged in internally constructing representations and operating on these. From an interactionist perspective, learning with media can be thought of as a complementary process within which representations are constructed and procedures performed, sometimes by the learner and sometimes by the medium (Kozma, 1991).

How did the capabilities of computers facilitate the learning that occurred in the *ThinkerTools* project (White 1993)? First, the capability that computers have to present dynamic symbolic elements was used to create the representations of "objects in motion." This capability is very salient to a task domain for which motion is obviously important. It is also salient to novice students whose prior knowledge is either insufficient to create mental models of Newtonian motion or inaccurate such that the trajectories that they supply are contrary to scientific principles. Second, the capability of the computer to take input from the students and proceduralize these data was used to move the symbolic objects according to the laws of mechanics. That is, students could use the joy stick to "act" on these graphic objects in ways that corresponded to "force." Allowing students to manipulate "force" externally and examine the Newtonian effect on motion, as experts do internally with their mental models, quite likely made a significant contribution to the learning achieved in the White study.

What contribution did videodisk make to learning in the *Jasper* project (Van Hanenghan, et al., 1992; Cognition and Technology Group at Vanderbilt, 1992)? Firstly, the capability of video to present complex, dynamic social contexts and events helped students construct rich, dynamic mental models of these situations. The detailed, dynamic nature of these mental models allows students to draw more inferences than they can from mental models constructed from text or even still pictures (Bransford, Sharp, Vye, Goldman, Hasselbring, Goin, O'Banion, Livernois, Saul, and the Cognition and Technology Group at Vanderbilt University, 1992). These structures are also more memorable than those constructed with text (Baggett, 1989). Had text been used instead of video, the construction of these mental models would rely less on information in the text and more on information in students' heads (Beagles-Roos & Gat, 1983; Meringoff, 1982), information that is likely to be incomplete or inaccurate for those with little prior knowledge.[2] Text also places more demands on reading ability for those who have not yet automated these skills. With these demands preempted by the video, the students can use their cognitive resources to learn the target problem solving strategies.

Secondly, the video contains a great deal of detail and information, information crucial to the solution of the problem. During the story, information about distances, available money, and other relevant conditions are embedded in objects and maps, and in what people say, do, and think, as this is acted out in the story. The random access capabilities of videodisk allow students to use a remote control device to pause, review, and search for information that they may have otherwise missed or forgotten. Identifying needed information and disembedding it from a context is an important component of learning to solve problems and this ability contributes to successful transfer and performance in subsequent real world situations.

Finally and most importantly, the visual and social nature of the story, as presented with video, is more likely to activate relevant situation-based prior knowledge so that students can use this to solve the problem . They are also more likely to connect their new learning to representations of situations as it is stored in memory. This will increase the likelihood that subsequently encountered similar problem situations will evoke the appropriate solution procedure. By repeating the same kinds of analyses and solutions in multiple contexts or situations with very different surface characteristics but common underlying task demands, these learned solution strategies are connected to a variety of situation schemas in memory and this promotes transfer across a variety of subsequently encountered problem situations (Spiro & Jehng, 1990). Application of the *Jasper Series* in the regular classroom involves several different video-based stories beyond the single one used in the study above. This should increase the likelihood that the strategies are recalled and applied in a wide variety of problem situations in the real world.

In summary, the learners in the *ThinkerTools* project benefited from the use of computers because the capabilities of this medium were employed to provide representations and perform or model operations that were salient to the task and that the learners had difficulty providing for themselves. Learners in the *Jasper* project benefited from the use of television because the capability of the medium was used to present problems embedded in complex social contexts that allowed students to connect their knowledge of solution procedures to real world-like problem situations. It is certainly the case that on occasion some learners, perhaps most, can and do supply useful representations and operations for themselves from the information that is available in the environment, regardless of the medium used. However, when learners have difficulty providing representations and operations that are sufficient for learning, either because of limited prior knowledge, limitations in working memory, or other reasons, they will likely benefit from the use of the capability of a particular medium to provide or model these representations and operations. Over time, these representations and operations become internalized such that students can generate for themselves what was generated for them by the medium (Salomon, 1993).

Implications for Theory

How does the analysis above contribute to a theory of learning with media? Clark would say it does not. Attributing media effects to their capabilities or attributes invokes Clark's (1983) criticism of the media attribute approach. Clark does not consider attributes to be variables in media theory because they are neither necessary or unique to a particular medium. Attributes, according to Clark (1983), ". . . [are] not exclusive to any specific medium . . ." (p. 451) and ". . . many different media could present a given attribute so there [is] no necessary correspondence between attributes and media" (p. 452). To illustrate Clark's point, you could use dynamic pictures with either television, film, or a computer-generated animation and, therefore, this symbolic attribute is not exclusive or unique to television. Conversely, you can have a medium, such as television, without its associated attributes, such as dynamic pictures (e.g., one could show a still picture or static text on the screen), and therefore the attribute is not necessary for the medium.

However, a distinction must be made between attribute as a capability of a medium and the variability of its use. In the development of theory, Dubin (1969) defines an "attribute" as the property of a thing distinguished by the quality of being present, while a "variable" is the property of a thing that may be present in degree (p. 35). The <u>attributes</u> of a medium are its <u>capabilities</u>; the capabilities of a medium are always present. It is a necessary, defining attribute of television that it is capable of employing dynamic pictorial symbol systems, even if this capability is unused, and it is not at all a capability of radio. A medium is distinctive to the extent that its defining cluster of attributes is unique, that is, different from the defining clusters of other media. This has two implications for the focus of our theories: We must specify the causal mechanisms by which cognitive and social processes are influenced as students interact with a medium's defining capabilities (i.e., attributes). And we must specify the appropriate uses of these capabilities (i.e., variables), that is, the ways in which these capabilities may be used to influence the learning for particular students, tasks, and situations.

The use of dynamic visual symbol systems is a capability of video that distinguishes it from text and radio. Understanding how learners interact with video-based presentations and how this differs from the processing of text-based or audio-linguistic information is an important component of media theory and is crucial to understanding how media can influence learning. Both video and computers share the capability of displaying dynamic pictures but they are distinguished by the fact that the processing capability of computers can be used to move these pictures based on rules evoked by the decisions and actions of the users. Understanding the ways in which students use the unique processing capabilities of the computer is essential to understanding the influence the computer may have on learning and to building media theory. The other half of media theory is understanding when and how to employ these symbolic and processing capabilities so that cognitive and social processes, so influenced, result in learning for certain, students, tasks, and situations.

However, Clark contends that even if such attributes are considered to be <u>media</u> attributes and even if research shows these attributes are associated with learning, they do not play a role in instructional theory unless the relationship between them is a <u>necessary</u> one. Clark contends that ". . . theories seek necessary conditions" (1983, p. 452) and such necessary conditions are ". . . the foundation of all instructional theories" (p. 453). On the other hand, Clark states that attributes are ". . . occasionally sufficient but not necessary contributors to learning" (p. 452) and therefore they ". . . may contribute to instructional design but not to theory development" (p. 451).

While Clark insists that instructional theory depends on necessary rather than sufficient conditions, Cohen and Nagel (1934) point out that the scientists concerned with necessary conditions are those interested in eliminating something undesirable, such as disease (p. 323). On the other hand, scientists interested in the production of something desirable, such as learning, are concerned with establishing conditions that are sufficient to bring it about (p. 323). Necessary conditions are those in whose absence an event cannot occur, while sufficient conditions are those in whose presence an event must occur (p. 322). It is of use to know those conditions without which learning will not occur. But for a design science, it is more important that instructional theories be based on those conditions under which learning will occur.

Given that learning fails to occur so frequently in our schools and work places, we must look for sufficient conditions in our theories, research, and designs. However, in constructing theories the sufficiency of conditions must be considered probabilisticly, rather than deterministicly as implied by Cohen and Nagel (1934). In the real world, as contrasted with the experimental laboratory, events are the outcomes of complex causal configurations which act conjointly. Causes which may be sufficient for learning in one situation may result in different net effects or may be canceled out as they are joined by other causes in different situations, even though the same causal mechanisms are at work in each (House, 1991). Consequently, our media theories and research must reflect both the capabilities of media and the complexities of the social situations within which they are used.

Implications for Research

The foundational assumptions and goals that guide educational research are shifting from a view of the world as a set of law-like relationships between observable causes and effects that act uniformly across similar situations to a world of interacting causes that join together to produce events (House, 1991). Within this paradigm, the goals of research are to isolate, as much as possible, the causal entities and structures that produce events and to describe, as much as possible, the complex interactions of these events in particular social situations. Rather than causes and effects, then, we are looking for causal mechanisms, which are the underlying processes that produce events. And rather than general laws we are looking for sufficient tendencies, which are the net effects of these mechanisms as they operate in complex social situations. Consequently, the goal of research for applied or design scientists is to identify the particular causal elements that "tip the balance" (to use House's term) and produce desired events within specific situations.

The goals of specifying mechanisms and describing interactions roughly correspond to the analytic and systemic approaches to educational research described by Salomon (1991) and issues of internal and external validity raised by Ross and Morrison (1989). The goal of the analytic approach is to manipulate and control situations so as to increase internal validity and isolate specific causal mechanisms and processes. In the past, this has typically been done by conducting experimental studies (of the sort reviewed by Clark) in which an independent variable is isolated by the experimental design and its effect on a dependent variable is measured. This approach has resulted in limited understanding of the phenomena, primarily because the "cause" and the "effect" were examined but rarely the "causal mechanism." This is similar to examining the effect of a tornado descending on a town by taking photographs before and after the event. These photographs allow us to observe the extent of the damage but not the process by which the damage was wrought. To understand this process we would need to make fine-grained, moment-by-moment observations.

The goals of the analytic approach would furthered, then, by observations of the phenomenon throughout the period of change and by a high density of observations relative to the rate of change (Siegler & Crowley, 1991). These goals can also benefit from including "process" as well as "outcome" data in our observations. The use of think aloud protocols (Ericsson & Simon, 1993), eye fixations, and log files of events increases the amount of information that we have on the processes by which change occurs as learners interact with our interventions in certain ways. Methodologies that provide more direct access to causal mechanisms reduce the need for comparative experimental designs which are structured so that conclusions about mechanisms are drawn indirectly by inference.

The second approach discussed by Salomon (1991) is the systemic approach. This approach is based on the assumption that each event, component, or action in the classroom has the potential of affecting the classroom as a whole. These variables act on each other in interdependent ways. Changing one variable may have dramatic and perhaps unanticipated effects as it propagates through the complex web of relationships among variables in the system. The goal of this approach is to describe the patterns of relationships among a system of components and events as they interact and mutually define each other in real situations. Observing the interaction of these variables as it occurs in natural settings increases the external validity of research findings.

Salomon (1991) suggests the use of quantitative methods, such as Guttman's Smallest Space Analysis (Guttman, 1969), to statistically establish the interrelationship among variables such as use of the computer, teacher talk, social interaction among students, perceived self-efficacy, ability, effort, excitement, and achievement. The use of this statistical analysis over time can show the shifting interrelationships as an intervention is introduced into the classroom. Alternatively, ethnographic or naturalistic methods can be used to identify and analyze the "whys," "hows," and interrelationships of various instructional dimensions as they are emerge in classroom activity (Neuman, 1989). Prolonged observation, interviews, and artifact analysis provide a richness of detail about the social processes within which cognition is embedded. Such details are often missing from quantitative data.

Salomon (1991) points out the complementarity between analytic and systemic approaches. They can be used together to identify causal mechanisms and then to observe how they interact in complex social situations. Related more specifically to media research, the analytic approach and process methodologies can be used to isolate particular media attributes and observe how learners' interactions with these to influence learning processes. The systemic approach and quantitative or ethnographic methodologies can be used in classroom situations to examine how these media-related causal mechanisms interact with other mechanisms to influence learning conjointly. Brown (1992) describes how she uses a coordinated mix-and-match approach where large scale studies are complemented by in-depth analyses of a few individuals or groups of the children. This coordinated approach is used to specify the roles of teacher, students, curricula, and computer support within the classroom context.

White (1993) used a variety of research approaches in her *ThinkerTools* project. In addition to collecting achievement and transfer data, she made observations of group discussions in the classroom, examined students' notebooks, and interviewed students and asked them to think out loud while they solved problems.

But more the most part, these approaches are not yet commonly used. The extended the research methods recommended here would generate additional information on the relationship between media and learning over the use of traditional methods alone. For example, future research on the *Jasper* project would benefit from the collection of data on how it is that groups of students decompose and solve problems and how it is that they use video to do this: How often do students generate questions and what kinds are they? Do they use the video to answer these questions? If they do not search the video, is the information that they generate recalled from a previous viewing or is it based on general, world knowledge? If they use information in the video what information is used and how do they search for it? How does this information, in turn, influence subsequent questions or the discourse among students? Research on this project would also benefit from controlled studies in which groups of students receive similar information embedded in text-based or video-based stories. How do students process these stories differently? How do they search them differently? What information do they remember from each and is it structured differently?

Answers to questions such as these provide both a list of elemental, media-related causal mechanisms and descriptions of how they interact differently with other mechanisms in a range of educational situations. This information informs both theory and practice much more than a information from comparative studies that neither examine mechanisms or contextualize their findings.

Implications for Practice

Clark (1983, 1985) would contend that the findings in the studies cited above confound medium with content or method and the learning achieved was due to these latter factors, not the medium used. Consequently, it is the selection of the method not the medium that is of practical importance for learning. Selection of media, Clark would say, deals only with the efficiency or expense of delivering these methods. He contends that ". . . when we begin to separate method from medium we may begin to explain more significant amounts of learning variance" (Clark, 1983, p. 449).

Quite certainly the posting of motivational questions, the progression of models, the formulation of "laws," the guidance of teachers, and the use of student groups all contributed to learning in the *ThinkerTools* project. And the use of socially rich contexts, the decomposition of problems, the particular strategies used to solve problems, the guidance of teachers, and the use of student groups all contributed to learning in the *Jasper* project. But the fact that other factors contribute to learning does not preempt a role for media.

Indeed, Clark's separation of media from method creates an unnecessary and undesirable schism between the two. Medium and method should have a more integral relationship (Ross & Morrison, 1989; Winn, 1989; Kozma, 1991). Both are part of the instructional design. In good designs, a medium's capabilities enable methods and the methods that are used take advantage of these capabilities. If media are going to influence learning, method <u>must</u> be confound with medium. Media must be designed to give us powerful new methods, and our methods must take appropriate advantage of a medium's capabilities.

Learning resulted in the *ThinkerTools* project precisely because White (1984, 1993) used the computer's capabilities to create symbolic representations similar to the mental representations that experts create for themselves and she made these representations respond to students' manipulations much like mental representations behave when experts reason with them. In the *Jasper* project, video's capability to display dynamic pictures was used to present complex social situations that help students associate solution strategies with problem contexts.

The integration of media and method, in turn, with the educational context is also important (De Corte, 1993). The image of students working one-on-one with a computer in isolation from other students, or even a teacher, evokes memories of the teaching machine and the Skinner Box, a paradigm that has been rejected for good reason. Media will only make a significant contribution to learning in our schools if their application is designed into complex social and cultural environments of learning (Pea, 1992; Newman, Griffin, & Cole, 1989) and made widely accessible, especially to those students most at risk of school failure (Kozma & Croninger, 1992). And media will contribute to school reform only to the extent that these systems are designed around the constraints and tasks that confront teachers and classrooms (Cuban, 1986; Kerr, 1989)

Traditional models of instructional design do not address the complex interrelationships among media, method, and situation. In general, they are not compatible with constructivist, social models of learning, being as they are derived from behavioral models (Winn, 1989). Perhaps it is also time to reframe our notions of design along with our notions of media. Perhaps a more productive approach would be to view the design process is a dynamic, creative interaction—or conversation, to use Schön's term (1987)—between the designer, the situation, and the medium in which the design both shapes and is shaped by each of these factors. The capabilities of a medium constrain what it is designers can do, as do features of a situation. But these capabilities and features also enable designers; they provide the designer with resources and suggest things that might be done with them. Media capabilities have changed considerably since the time of the studies reviewed by Clark (1983); they will change even more in the near future. These developing capabilities may, in turn, change the ways in which designers interact with media and enable more powerful designs which emerge from this interaction. But this change will depend as much on the mind set of designers as on the capabilities of media. This requires a shift in perspective.

From an interactionist perspective, the "conversation" between designer, medium, and situation does not stop when the design is "finished." The result of the design process is not an inert, objective object. Rather, this object can be viewed as a rhetorical statement that the designer makes about desirable actions, beliefs, and values (Buchanan, 1989). In this way, the designed object is the first turn in a conversation between the designer and the intended users. The design itself does not emerge until the users interact with it—take their turn in the conversation. The emergent design will be influenced by the goals, beliefs, and knowledge of the users, as well as the intentions of the designer, as embedded in the designed object. The conversation will be different for different users and perhaps for subsequent uses by the same user. From this perspective, the task of the designer is to use the capabilities of the medium to create objects that generate interesting and effective "conversations"—ones that influence learning.

The emerging National Information Infrastructure (NII) will be an excellent test bed for our evolving theories, research methodologies, and instructional designs. The NII will combine telephone, video, and computer technologies into one seamless, interactive digital medium (Information Infrastructure Task Force, 1993; Stix, 1993). This network will connect homes, business, and schools. An understanding of the way that media capabilities, instructional methods, and cognitive processes interact in complex social situations will allow us to take advantage of these capabilities. The combined capabilities of these media, and the access to a range of social situations and processes that they bring, provide designers with powerful new tools that they can use to construct their designs.

With these capabilities, students in science classes can combine data on local water quality with self-generated video stories about the personal importance of their lake or stream and post these in a national or regional resource-base of text, video, and data. Data points can be aggregated across regions and analyzed to determine trends and the stories can be examined to build meaning and personal relevance out of these findings. In their social studies classes these students can study environmental legislation by observing congressional debates and sending email to their representatives. Or students from different locations can engage in voice-video debates to discuss the relative impact of water quality legislation, water diversion, or environment-related plant closings on the quality of water and on their quality of life.

How this new technology will be used is not yet clear. But enabled by its capabilities, liberated by new models of design, and informed by media theory and research, designers may find new ways to engage students in interactions within these technological environments, interactions that may tip the balance in favor of learning.

Conclusion

The field of educational technology is reexamining its foundational assumptions and questions (Duffy & Jonassen, 1992; Hlynka & Belland, 1991). This article is meant to contribute to that effort. I believe that 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 restructuring of schools and the improvement of education and training.

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[1] It is important to note that because technology changes over time, so too does the definition of a particular medium. For example, the advancing speed and capacity of CPUs have made it possible to employ pictures and other dynamic symbol systems with computers in a way that was not possible before the 1970's. Thus, the definition of computers has changed to include these symbol systems. Early studies of computer-based instruction (such as those reviewed by Clark, 1985) were actually studying a different, less capable medium than we are examining here.

[2] Quite likely, this is the reason why learning concepts that are dissonant with prior knowledge is so difficult with text (Dole, Niedefhauser, & Hayes, 1991). With text, the information that students remember is their prior knowledge; often, they do not even perceive a dissonance between prior knowledge and information in the text, even when they are prompted to do so.