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Multimedia Information and Learning

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Multimedia is being used increasingly to provide computer based instruction. One reason for this trend may be the assumption that multimedia information helps people learn. To find out whether there is empirical support for this assumption, this paper reviews studies from a wide variety of fields to show that multimedia -may be able to help people learn more information more quickly compared to traditional classroom lecture. Redundant multimedia does not always improve learning compared to "monomedia." Specific situations in which multimedia information may help people to learn include (a) when the media encourage dual coding of information, (b) when the media support one another, and (c) when the media are presented to learners with low prior knowledge or aptitude in the domain being learned. There is empirical support for concluding that specific multimedia can be used to help people learn specific kinds of information.

Multimedia is the use of text, graphics, animation, pictures, video, and sound to present information. Since these media can now be integrated using a computer, there has been a virtual explosion of computer based multimedia instructional applications. These applications run the gamut from serious computer-based tutorials for adults to the new category of "edutainment" products for children. These very diverse applications seem to share a common assumption-multimedia information helps people learn.

This assumption seems to be based more on personal opinion than on scientifically based fact. People enjoy multimedia, prefer multimedia learning materials, and believe that multimedia helps them learn (e.g., Bosco,1986; Bryant, Brown, Silberberg, & Elliot, 1980; Fletcher, 1989, 1990; Holliday, Brunner, & Donais, 1977; Rigney & Lutz, 1976; Samuels, Biesbrock, & Terry, 1974; Sewell & Moore, 1980). These beliefs are exploited by the marketers of multimedia hardware, software, and services to hype their products. One widely cited (e.g., "Eloquent Idea," 1992; Hofstetter, 1994; Staff, 1990) and completely unsupported assertion is that, "People generally remember 10% of what they read, 20% of what they hear, 30% of what they see, [and] 50% of what they hear and see..." (Treichler, 1967, p. 15).

So, people generally believe that multimedia helps them learn. But do empirical studies support this belief? This paper tries to cut through the hype and the enthusiasm to determine whether there is empirical support for the assumption that multimedia information presentation improves learning.

CLASSROOM LECTURE VERSUS MULTIMEDIA INSTRUCTION

A good place to start is the classroom. The current, standard form of instruction is traditional classroom lecture. It seems reasonable to compare learning when the information is presented via classroom lecture to learning when the information is presented via computer-based multimedia.

Meta analyses (Bosco, 1986; Fletcher, 1989, 1990; Khalili & Shashaani, 1994; Kulik, Bangert, & Williams, 1983; Kulik, Kulik, & Bangert-Drowns, 1985; Kulik, Kulik, & Cohen, 1980; Kulik, Kulik, & Schwalb, 1986; Schmidt, Weinstein, Niemic, & Walberg, 1985) examined over 200 studies that compared learning information that was presented in a traditional classroom lecture to learning the same information presented via computer-based multimedia instruction. The students were in K-12, higher education, industry, and the military. The information that was learned included biology, chemistry, foreign languages, and electronic equipment operation. The control group usually learned the information via classroom lecture or lecture combined with hands on equipment experience. The comparison group usually learned the information via interactive videodisc or some other kind of computer-based instruction. The researchers most often measured learning using tests of achievement or performance. Over this wide range of students and topics, the meta-analyses found that learning was higher when the information was presented via computer-based multimedia systems than traditional classroom lectures.

Another very significant finding was that learning appeared to take less time when multimedia instruction was used. For example, Kulik, Bangert, and Williams (1983) found one study that recorded an 88% savings in learning time with computerized instruction (90 minutes) versus classroom instruction (745 minutes) and another study that recorded a 39% savings in learning time (135 minutes for computerized instruction versus 220 minutes for classroom instruction). Both studies involved computer simulation instruction in physics. Kulik, Kulik, and Schwalb (1986) identified 13 studies in which students using computers mostly for tutoring learned in 71% less time than students in traditional classroom instruction. In a comparison involving eight studies, Kulik, Kulik, and Cohen (1980) found that computer-based instruction took about 2.25 hours per week while traditional classroom instruction took about 3.5 hours, a 36% savings in learning time. However, as impressive as these findings are, there may be other explanations for these results.

Instructional Method

For example, computer-based instruction may force the instructional designer to better organize and structure the learning material compared to traditional classroom lecture. This improved information organization may be responsible for the learning advantages associated with computer-based multimedia instruction.

Interactivity

Interactivity can be thought of as mutual action between the learner, the learning system, and the learning material (Fowler, 1980). Computer based multimedia instruction tends to be more interactive than traditional classroom lectures.

Interactivity appears to have a strong positive effect on learning (Bosco, 1986; Fletcher, 1989, 1990; Verano, 1987). One researcher (Stafford, 1990) examined 96 learning studies and, using a statistical technique called effect size (difference between means of control and experimental group divided by standard deviation of the control group), concluded that interactivity was associated with learning achievement and retention of knowledge over time. Similar examinations of 75 learning studies (Bosco, 1986; Fletcher, 1989, 1990) found that people learn the material faster and have better attitudes toward learning the material when they learn in an interactive instructional environment.

So, the learning advantage of computer-based multimedia instruction over traditional classroom lecture may be due to the increased interactivity of multimedia instruction rather than the multimedia information itself.

Control of Learning Pace

Computer-based multimedia instruction allows the learner to personally set the pace of learning. Traditional classroom instruction does not. Set of paced learning is probably a more effective way to learn because the learner can move on to new material when the learner is ready. So, control of the learning pace is another possible explanation for the learning advantages associated with computer-based multimedia instruction.

Novelty

Information presented via multimedia may be more novel and stimulating than information presented via traditional classroom lecture. This explanation has some support from empirical studies. Analyses (Clark, 1983, 1985; Clark & Craig, 1992; Khalili.,& Shashaani 1994; Kulik, Bangert, & Williams, 1983) of nearly 40 multimedia studies found that, compared to traditional classroom lecture, learning improvements were higher for groups that used multimedia for four weeks or less, but the learning advantage tailed off fairly strongly after eight weeks. The initial, higher learning advantages for multimedia may have been due to the novelty of the multimedia instruction. As students became more familiar with the multimedia, however, the novelty wore off, and the learning advantages decreased. It appears that the novelty of multimedia information has a slight, temporary, positive effect on learning.

So, computer-based multimedia information presentation appears to offer general learning advantages over the traditional classroom lecture presentation of information. Computer-based multimedia information seems to improve the level and rate of learning. However, instructional method, interactivity, control of learning pace, and novelty are alternative explanations for these advantages.

REDUNDANT MULTIMEDIA VERSUS "MONOMEDIA"

One way to try to eliminate the alternative explanations is to compare learning when the information, instructional method, interactivity, and pace are the same, and novelty is reduced. For example, this situation occurs when the same verbal information is presented using audio and printed text together (redundant multimedia) versus audio text alone "monomedia"). Any performance differences found in these conditions are probably due to the media.

Some studies (Levie & Lentz, 1982; Mayer & Anderson, 1991, 1992; Nugent, 1982; Pezdek, Lehrer, & Simon, 1984; Sevcrin, 1967) looked at this kind of information presentation. These studies found that two redundant media seem to improve learning better than one medium. For example, Mayer and Anderson (1991) had college students (a) hear a verbal description, simultaneously with an animation explaining how a bicycle pump works (redundant multimedia), (b) hear the verbal description only “monomedia"), (c) see the animation only "monomedia"), or (d) receive no training. On a problem-solving test the students who heard a verbal description simultaneously with the animation (redundant multimedia) performed better than the other students. In another study (Nugent, 1982), the highest learning levels were obtained when elementary school students were presented information via combined text and pictures (redundant multimedia) or combined audio and pictures (redundant multimedia) compared to the same content presented via text alone ("monomedia"), audio alone ("monomedia"), or pictures alone ("monomedia").

However, redundant multimedia does not always lead to improved learning. For example, Severin (1967) found that children who learned animal names using two media (audio combined with print) did not show better animal name recognition than children who learned with one medium (print alone).

These inconsistent results may be due to the way in which the media are used. The next section identifies specific circumstances in which multimedia appears to improve learning. It seems that some situations more effectively improve multimedia learning than other situations.

SITUATIONS IN WHICH MULTIMEDIA HELPS PEOPLE LEARN

There is empirical support for concluding that multimedia information provides learning advantages in several specific situations.

When the Media Support Dual Coding of Information

According to dual coding theory (Paivio, 1971, 1986, 1991; Clark & Paivio, 1991), information is processed through one of two generally independent channels. One channel processes verbal information such as text or audio. The other channel processes nonverbal images such as illustrations and sounds in the environment. Information can be processed through both channels. This occurs, for example, when a person sees a picture of a dog and also processes the word "dog." Information processed through both channel is called referential processing and has an additive effect on recall (Mayer & Anderson, 1991; Paivio, 1967, 1991; Paivio & Csapo, 1973 . Learning is better when the information is referentially processed through two channels than when the information is processed through only one channel. Referential processing may produce this additive effect because the learner creates more cognitive paths that can be followed to retrieve the information.

Empirical multimedia studies support this idea. For example, in the Severin (1967) study mentioned earlier, animal name recognition accuracy was highest when children were presented the names via simultaneous audio and pictures (verbal and nonverbal channels). Children who received the same information via audio and print (two verbal channels) did not outperform students who received the information via print alone (verbal channel). Similarly, in the Nugent (1982) study, the highest learning levels were found when students were presented information via combined text and pictures (verbal and nonverbal channels) or combined audio and pictures (verbal and nonverbal channels) compared to the same content presented via text alone (verbal channel), audio alone (verbal channel), or pictures alone (nonverbal channel).

In the Mayer and Anderson study (1991), the students who heard a verbal description simultaneously with the animation (verbal and nonverbal channels) performed better on a problem-solving test than the students who heard the description only (verbal channel), saw the animation only (nonverbal channel), or got no training. The same researchers (Mayer & Anderson, 1991, 1992) also performed a series of studies in which an auditory explanation of bicycle pump or automobile brake operation was presented before or during an explanation showing the same information. The mechanically-naive students who heard the explanation with the animation (combined verbal and nonverbal channels) performed better on a creative problem-solving test than the students who heard the verbal explanation before the animation (separate verbal and nonverbal channels).

However, there are cases in which presenting verbal and nonverbal media did not appear to lead to dual coding of the information, and, hence, improved learning. For example, in a classroom test, Samuels (1967) found that a related picture accompanying a simple short story interfered with the ability of poor first grade readers to learn to read the 50 words in the short story. In a laboratory study, Samuels (1967) presented words alone or words with identifying pictures to kindergarten children who were learning to read four words. After the children saw each word or word and picture, the experimenter read the word to the children. When the experimenter tested learning using only words, the children who saw only words performed better than the children who saw words with pictures. For this latter test, it appears that the pictures distracted the children. A review of related literature (Samuels, 1970) also concluded that pictures interfered with learning to read.

The studies described in this section support the idea that, except for learners who may be distracted by illustrations, learning may be improved when multimedia information encourages learners to referentially process the information in a dual coding fashion.

When the Media Support One Another

Multimedia information seems to improve learning when the media show closely related, supportive information. For example, Bransford and Johnson (1972) presented short, ambiguous text passages to high school students. Before seeing each passage, one group of students saw a picture that explained the ambiguous text. The researchers believed that this picture provided a context for understanding the ambiguous text. The students who saw the picture recalled more ideas from the text than the students who did not see the picture. It appears that the picture helped the students to interpret the meaning of the text.

In a review of the literature on text and illustrations, Levie and Lentz (1982) found that text that was accompanied by illustrations showing what was described in the text was learned better by children than text that was not accompanied by illustrations. For example, Peeck (1974) asked fourth grade children to read a story with supportive illustrations or without illustrations, measured learning via multiple choice, verbal recognition tests, and found that retention was better when the text was accompanied by supportive illustrations. Levie and Lentz estimated that children reading illustrated text learned one-third more than children reading non illustrated text, especially when the illustrations supported information presented in the text. These results are consistent with the dual coding theory described above. Supportive illustrations may also make abstract relationships more concrete and simplify the complex (Winn, 1987, 1989).

Levie and Lentz (1982) also found that illustrations that did not show what was described in the text did not improve learning. For example, Sewell and Moore (1980) added to textual material small cartoons that did not support the textual information. Although the students enjoyed the cartoons, the cartoons did not affect learning. Evans and Denney (1978) found that the short phrases in picture phrase combinations were recalled better as the pictures and phrases became more related. Using verbal captions, Bahrick and Gharrity (1976) showed that pictures helped people recall captions that were related to the pictures, but not captions that were unrelated.

Also, as Samuels' (1967) work with poor first grade readers suggested earlier, there appear to be some cases in which the addition of the nonverbal medium actually decreases learning. Poor first grade readers appeared to be distracted by the supporting illustrations that were added to the text.

These results suggest that the mere presence of illustrations does not improve the learning of textual information. The illustrations must show information that is presented in the text and the learners must be able to avoid getting distracted by the nonverbal media. It appears that supportive illustrations help explain the textual material and allow learners to build connections between the verbal (text) and nonverbal (illustrations) information (Paivio, 1971, 1991; Clark & Paivio, 1991). This referentially processed, dual coded information leads to improved learning.

When Media Are Presented to Learners with Low Prior Knowledge or Aptitude in the Domain Being Learned

Multimedia information appears to be more effective for learners with low prior knowledge or aptitude in the domain being learned. Mayer (1993) believes that this is because the multimedia helps low domain knowledge learners to connect the new knowledge to prior knowledge or, for learning systems such as a bicycle pump, to build a cognitive model of the system. Multimedia may also make more important information more obvious. However, learners with high domain knowledge have a rich source of prior knowledge that can be connected to the new knowledge. These learners can make these connections or build cognitive models with text alone. Also, learners with high domain knowledge are more likely to know which information is important and on which information they should focus their attention.

In one study (Mayer & Gallini, 1990), college students read text with and without illustrations that explained the operation of automobile drum brakes. For college students with low prior knowledge of automobile drum brake operation, the illustrations improved their recall of explanative information and their ability to solve problems related to the explanations. For college students with high prior knowledge, the explanative illustrations did not affect their performance. Another study (Kunz, Drewniak, & Schott, 1989) found that for college students with low prior meteorology knowledge, use of pictures in text correlated positively with comprehension. But, for college students with high prior meteorology knowledge, use of pictures in text did not correlate with comprehension.

Studies by Blake and Wardle (cited in Levie & Lentz, 1982) found that aptitude affected learning from multimedia. In the Blake study, college students with low or high aptitude in spatial and mental abilities learned the pattern of movement of five chess pieces via moving pictures (film), static pictures, or static pictures with arrows indicating motion. The students with low aptitude performed better in the conditions with moving pictures or static pictures with motion arrows than the condition with static pictures alone. However, the students with high aptitude performed similarly on all three kinds of pictures.

Wardle (cited in Levie & Lentz, 1982) gave 800-word textual passages on various science topics to seventh grade students. Some of the passages included supporting illustrations. During a comprehension test, the students were allowed to look at the materials. Poor readers performed better when the passages included illustrations. For good readers, the illustrations had no effect.

The results of these studies suggest that multimedia is most effective for people with low prior knowledge or aptitude in the domain being learned. This may be because experts already have a cognitive model and large amounts of information for new knowledge to connect to, but novices do not. Alternatively, novices may not know which information is important and on which information they should focus their attention.

So, empirical studies support the idea that multimedia may help people learn. Multimedia that encourages the information to be processed referentially, building dual coded verbal and pictorial cognitive representations, seems to improve learning. For example, relevant, supportive illustrations improved the learning of textual stories. Multimedia also seems to be more effective for helping learners with low prior knowledge or aptitude in the domain being learned.

ALLOCATING MEDIA FOR PRESENTING INFORMATION

Multimedia may also improve learning by allowing instructional designers to use the most effective medium to present specific information. Although media selection models based on learning objectives (e.g., Allen, 1974), data-to-medium rules (e.g., Arens, 1992; Arens, Miller, Shapiro, & Sondheimer, 1988), communication goals (e.g., Elhadad, Seligmann, Feiner, & McKemkii, 1989; Feiner & McKeown, 1990, 1991a, 1991b) or learner characteristics, tasks, and instructional settings (e.g., Reiser & Gagné, 1982) are available, these models appear to be based on experienced judgment rather than on empirical studies. To improve the ability of instructional designers to make effective media allocation decisions, the following section summarizes the limited number of empirical studies that suggest how to allocate specific media for successfully presenting specific kinds of information to be learned. The results arc shown in Table 1.

Table 1

Empirically-Supported Suggestions for Allocating Media

Information to be Learned	***Suggested Presentation Media***
Assembly instructions	Text with supportive pictures
Procedural information	Explanatory text with a diagram or animation
Problem solving information	Animation with explanatory verbal narration
Recognition information	Pictures
Spatial information	Pictures
Small amounts of verbal information for a short time	Sound
Story details	Video with a soundtrack (or text with supportive illustrations)

Assembly Instructions

To learn assembly instructions, it appears that text and pictures work well. Bieger and Glock (1981) found that people assembled with fewer errors when they received spatial information via text, but they performed the assembly task more quickly when they received spatial information via pictures. In another study (Stone & Glock, 1981), college students who used text with pictures made fewer errors on an assembly task than college students who used text alone. Apparently the best way to learn an assembly task is to acquire both spatial and verbal knowledge about the task steps.

Procedural Information

To present procedures for operating a device, it appears that using a diagram and explanatory text helps people acquire a cognitive model of how the device works. Studies (e.g., Kieras, 1984; Kieras & Bovair, 1983, 1984) found that this device model allows people to infer procedures more quickly than people who learn about the device by using repetition without full comprehension. Motion sometimes helps people learn procedures better than still pictures (e.g., Spangenberg, 1973).

Another study (Palmiter & Elkerton, 1991) found that text was better than animation for presenting procedural information. On an immediate test, people who saw animated demonstrations learned HyperCard authoring procedures faster and more accurately than people who saw only text. However, seven days later the people who saw only text were faster and as accurate as the people who saw animated demonstrations. Perhaps the textual procedures were learned better than the animated demonstrations due to differences in processing effort (e.g., Jacoby, Craik, & Begg, 1979; Salomon, 1984; Walker, Jones, & Mar, 1983). The text learners may have expended more effort to read and understand the information, resulting in improved long-term encoding of the information. But the people who watched the animated demonstrations may have passively observed the demonstrations without processing the information as well. The immediate test did not emphasize these differences in long-term encoding. However, the delayed test did. The results of the delayed test suggest that the animated procedures faded from memory much more than the textual procedures.

Problem-Solving Information

To learn problem-solving information, an animation with verbal narration was shown to be effective (Mayer & Anderson, 1991, 1992). People who saw an animation with verbal narration did better on a bicycle pump problem-solving test than people who got no training, saw the animation only, or heard the verbal description only.

To perform mathematical problem-solving, graphical presentations of information can improve performance compared to textual presentations (Moyer, Sowder, Threadgill-Sowder, & Moyer, 1984; Reed, 1985; Threadgill-Sowder & Sowder, 1982; Threadgill-Sowder, Sowder, Moyer, & Moyer, 1985). For example, one study (Threadgill-Sowder, Sowder, Moyer, & Moyer, 1985) found that grade school students who scored in the lowest quartile on a cognitive restructuring test (Hidden Figures Test) were able to improve their scores when the story problems in the test were presented using drawings that organized the problem data. Another study (Moyer, Sowder, Tlireadgill-Sowder, & Moyer, 1984) found that children in grades 3 to 11 solved mathematical word problems better with text and illustrations of the problem elements than text alone. The illustrations were more helpful to the low-ability readers than the readers with more ability. It appears the illustrations helped make the word problems more concrete, easier to understand, and, therefore, easier to solve.

Recognition Information

To communicate information that people need to recognize, pictures are extremely effective. In one study (Shepard, 1967), people looked at 600 pictures, sentences, or words. On an immediate test, recognition accuracy was 98% for pictures, 90% for sentences, and 88% for words. Another study (Nickerson, 1968) found that people had 63% recognition accuracy for a group of 200 black and white photographs one year after initial viewing. Other researchers (Standing, Conezio, & Haber, 1970) showed people 2,560 photographs for 10 seconds each. After three days, the study participants recorded recognition accuracy of over 90%. Read and Barnsley (1977) showed adults pictures and text from the elementary school books they used 20 to 30 years ago. Recognition accuracy rates for pictures and text were better than chance, with pictures alone being recognized more accurately than text alone. Finally, Stoneman and

Brody (1983) found that children in visual or audiovisual conditions recognized more products in commercials than children in an auditory only condition. Pictures seem to allow very rich cognitive encoding that allows surprisingly high recognition rates, even years after the initial encoding took place.

Spatial Information

Illustrations are superior to text when learning spatial information. For example, Bartram (1980) arranged for college students to learn how to get from a starting point to a destination using a minimum number of buses. The researcher presented the bus route information via maps or lists and asked the students to provide as quickly as possible the correct list of bus numbers in the correct order. Bartram measured the time it took to correctly complete each bus route task. The study found that the students learned the bus route information more quickly when they used a map than when they used lists. Bartram believed that the students performed a spatial task, and the maps were superior to lists because the map presentation of information is consistent with people's preferred internal representation of spatial information.

In an exploratory study, Bell and Johnson (1992) allowed four people to select pictures or text for communicating instructions for loading a battery into a camera. Qualitative results showed a strong preference for pictures rather than text. The researchers believed that the information to be communicated was spatial, and that the results supported the hypothesis that spatial information should be presented pictorially.

A study by Garrison (1978) supported the idea that spatial relations are recalled and recognized better by children when the spatial relations are presented via story text and illustrations rather than story text alone. Also, a series of studies by Dwyer (1967, 1978) found that illustrated text was better than text alone when students were tested on spatial information using a drawing test.

Pictures appear to be an effective way to learn spatial information. This may be because spatial information tends to be encoded spatially (e.g., Kosslyn, 1973, 1975, 1976; Kosslyn, Ball, & Reiser, 1978) rather than verbally or by what it means (i.e., semantically).

Small Amounts of Verbal Information

Sound appears to be an effective way to communicate a small amount of verbal information for a short period of time. For example, Murdock (1968) found that recognition for items in a nine item verbal list was better with an auditory presentation than with a visual presentation. Another study (Watkins & Watkins, 1980) found better short-term memory for a few verbal items when the items were presented via the auditory mode rather than the visual mode. A review of the related literature (Penney, 1975) concluded that, for tasks involving short-term memory, auditory presentation was better than visual presentation. This conclusion appears to be appropriate for about six verbal items. These results are consistent with Baddeley's (1983, 1988) concept of an articulatory loop for retaining verbal information in working memory and Conrad's (1964) finding that verbal information was coded via sound in short-term memory.

Story Details

For recalling story details, video with a soundtrack appears to be effective. Baggett (1979) found that, after a seven-day delay, college students who saw a dialogueless movie made fewer errors when recalling the story structure than college students who heard only equivalent text. On an immediate test of factual recall, children who saw a movie with an audio narration did better than children who heard a similar narration via radio (Barrow & Westley, 1959). Children recalled more story details when the story was presented via television with a narrated soundtrack than radio (soundtrack alone) (Beagles-Roos & Gat, 1983). Another study (Meringoff, 1980) found that children remembered more story actions when they saw a televised film with story narration than when they were read a very similar illustrated story.

Static pictures also appear to help children learn auditory, oral prose. Levin and Lesgold (1978) reviewed a dozen studies that examined the effect of pictures on children's ability to learn auditory, oral, fictional, stories. The pictures reflected the contents of the stories and learning was measured by short answers to factual questions. The reviewers found that related pictures improved learning of the oral prose.

It appears that both dynamic and static pictures help people learn story details and prose. This may be due to the ability of pictures to serve as a rich cognitive node to which verbal information can be connected and subsequently retrieved.

There is empirical support for concluding that certain media combinations seem to be better than others for helping people to learn specific kinds of information. These combinations may encourage the information to be processed in a way that is easier to encode, store, retrieve, and use.

CONCLUSION

This examination of a wide variety of empirical studies shows that multimedia information helps people learn sometimes. Computer-based multimedia instruction may help people to learn more information in less time than traditional classroom lectures. This is especially the case when the computer-based multimedia instruction is interactive and learner paced. The learning advantage for redundant multimedia over "monomedia" is not consistent. But this inconsistency is resolved when one takes into consideration the specific circumstances in which the media are presented. In particular, there is empirical support for concluding that multimedia information is most effective when:

1. It encourages the dual coding of information.
2. The media clearly support one another.
3. The media are presented to learners with low prior knowledge or aptitude in the domain being learned.

There is some empirical support for using specific multimedia to help people learn specific kinds of information. These advantages appear to be due to the ability of certain multimedia combinations to support the way people understand, organize, and access the information.

Unanswered Questions

Although this paper identified when and why multimedia seems to help people learn in several situations, some unanswered questions still remain. For example, is there an overall theory that we can apply to explain these empirical results and to predict future results? Since the media may affect how the learning material is encoded and retrieved, information encoding and retrieval theories (e.g., Anderson, 1976, 1983a, 1983b, 1993; Anderson & Reder, 1979; Mayer, Steinhoff, Bower, & Mars, 1995; Paivio, 1971, 1986, 1991; Reder, 1980) are possibilities. The effects of dual (verbal and pictorial) coding and elaboration are particularly promising (e.g., Najar, 1995a, 1995b).

In many learning situations, we present information using multimedia, but test learning using pencil and paper. If we use a different technique to present information, should we use a different technique to test learning? Multimedia learning may be artificially low because the media we use in our tests do not match the media we use in our information presentation.

Also, there is informal support for concluding that using multimedia to support learning by building (e.g., Papert, 1991), collaborative learning (e.g., Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989), and case-based teaching (e.g., Schank, 1991) help people to learn. Can we get strong, formal, empirical, support for these promising multimedia-based learning techniques?

When used properly, multimedia can help people to learn.

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