Does Multimedia Information Help People Learn?

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Table of Contents

Abstract

Multimedia is being used increasingly to provide computer-based instruction. While people generally believe that multimedia information helps people learn better than "monomedia" information, empirical support for this belief is scant. This paper reviews studies from a wide variety of fields to support the conclusion that multimedia information helps people learn—sometimes. (14 pages, 47 references)

Introduction

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. The general feeling seems to be that multimedia helps people learn "because it is fun." This feeling is exploited by the marketers of multimedia hardware, software, and services to hype their products. One widely cited 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).

These unsupported beliefs and claims can decrease the acceptance of multimedia. For example, parents and educators may be outraged when their expensive investments in multimedia education do not result in improved standardized test scores.

This paper tries to cut through the hype and the emotions to determine whether there is empirical support for the belief 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.

Several meta-analyses (analyses of analyses) (Bosco, 1986; Fletcher, 1989, 1990; 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 videodisk or some other kind of computer-based instruction. Learning was most often measured using tests of achievement or performance. Learning was found to be higher with the computer-based multimedia systems than with the 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 but 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 student, 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 student to set the pace of learning. Traditional classroom instruction does not. Self-paced learning is probably a more effective way to learn. 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. An analysis (Clark, 1983, 1985; Clark & Craig, 1992; Kulik, Bangert, & Williams, 1983) of several 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 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"

The preceding section compared learning the same information with computer-based multimedia to learning via traditional classroom lecture. Instructional method was one of the alternative explanations for the computer-based multimedia learning advantages. To separate the effects of media versus instructional method, this section examines empirical studies in which the information and instructional method were kept the same, but multimedia was used in one condition and "monomedia" was used in another condition. For example, this situation occurs when the same verbal information is presented using audio and printed text together (redundant multimedia) versus audio alone ("monomedia"). Any performance differences found in these conditions can be ascribed to the media rather than to the instructional method.

Some studies (Levie & Lentz, 1982; Mayer & Anderson, 1991, 1992; Menne & Menne, 1972; Nugent, 1982; Pezdek, Lehrer, & Simon, 1984; Severin, 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 (1) hear a verbal description simultaneously with an animation explaining how a bicycle pump works (redundant multimedia), (2) hear the verbal description only ("monomedia"), (3) see the animation only ("monomedia"), or (4) 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. The Menne and Menne (1972) study found that third grade students verbally recalled simple, four-line verses better with an auditory/visual presentation (redundant multimedia) than auditory alone ("monomedia") or visual alone ("monomedia"). In another study (Nugent, 1982), the highest learning levels were obtained when 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, other studies (Mayer & Anderson, 1992; Palmiter & Elkerton, 1991; Rohwer & Harris, 1975; Severin, 1967; Van Mondfrans & Travers, 1964) found that redundant multimedia did not improve learning. For example, Palmiter and Elkerton (1991) taught people computer user-interface steps by (1) an animated demonstration of the steps on the computer screen ("monomedia"), (2) procedural textual instructions on the computer screen ("monomedia"), or (3) combined animated demonstration and auditory procedural instructions (redundant multimedia). The study participants completed a test of the learned computer-interface steps immediately and seven days later. On the immediate test, the demonstration only group ("monomedia") was as accurate as the demonstration combined with text group (redundant multimedia), and both groups were more accurate than the text only group ("monomedia"). Adding the auditory verbal medium did not appear to improve immediate learning. However, on the delayed test, the text only group ("monomedia") was more accurate than both demonstration groups. It appears that the group that learned using one medium (text only) learned better than the group that learned using two redundant media (demonstration and auditory verbal). In the Severin (1967) study, a group that learned with two media (audio combined with print) did not show better animal name recognition than a group that learned with one medium (print alone).

So, the redundant use of media is not associated with consistent learning advantages. Redundant multimedia information does not generally help people learn better than "monomedia" information. The following section identifies specific circumstances in which multimedia appears to improve learning.

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 channels has an additive effect on recall (Mayer & Anderson, 1991; Paivio, 1967, 1991; Paivio & Csapo, 1973), possibly because the learner creates more cognitive paths that can be followed to retrieve the information.

Empirical multimedia studies support this idea. For example, Severin (1967) found that animal name recognition accuracy was highest when learners were presented the names via simultaneous audio and pictures (verbal and nonverbal channels). Learners 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, Nugent (1982) obtained the highest learning levels 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).

Mayer and Anderson (1991, 1992) performed a series of studies in which mechanically naive college students heard a verbal explanation and watched an animation showing how a bicycle pump or automobile drum brakes worked. The auditory explanation was presented before the animation or during the animation. The students who heard the explanation with the animation (combined verbal and nonverbal channels) performed higher on a creative problem-solving test than the students who heard the verbal explanation before the animation (separate verbal and nonverbal channels).

The learning advantage found when verbal and nonverbal information are presented together appears to be due to the dual coded integration of the information rather than to the repetition of the information. Levin, Bender, and Lesgold (1976) presented to children (1) one auditory sentence at a time, (2) the same sentence twice in succession, or (3) the sentence with a related illustration. A cued-recall test using short questions about the stories formed by the sentences found that learning was best with the sentence-illustration combination rather than the repeated sentences.

Paivio and Csapo (1973) presented words and pictures in a random sequence that included presenting (1) a word twice, (2) a pictorial representation of the word twice, or (3) the word once and the picture once. A free recall test found that learning was best when the word and picture were each presented once.

The results of the Levin, Bender, and Lesgold (1976) and Paivio and Csapo (1973) studies suggest that dual coding, rather than repetition, is responsible for the improvements in learning combined verbal-nonverbal information.

The studies described in this section support the idea that learning is improved when multimedia information encourages learners to process the information in a dual coding fashion.

<u>When the Media Support One Another</u>

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 the passages, 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 with no 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.

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. It appears that supportive illustrations allow learners to build connections between the verbal (text) and nonverbal (illustrations) information (Paivio, 1971, 1991; Clark & Paivio, 1991). This dual coded information leads to improved learning.

<u>When the Media Helps the Learner Construct Cognitive Models</u>

Multimedia appears to help people learn a system when it supports the development of a cognitive model of the system's operation. A cognitive model helps people learn how to solve problems with the system and to learn system procedures. For example, in the Mayer and Anderson (1991) bicycle pump study, the students who heard a verbal description simultaneously with an animation performed better on a problem-solving test than students who only heard the verbal description or only saw the animation. These findings may have been obtained because the combined media more easily allowed the students to create a cognitive model of the system than each medium alone.

Kieras and Bovair (Kieras, 1984; Kieras & Bovair, 1983, 1984) created a simple device consisting of two buttons, one switch, one selector dial, and four indicator lights. One group learned the procedures "by rote." The other group was given a diagram and explanatory text that helped the group members develop a cognitive model of how the device worked, then they were given the same procedure training by rote. The diagram and explanatory text included an overall explanation of the device (control panel for the phaser bank of the Star Trek Starship Enterprise), a description of the major components in the diagram, and a description of how the major components were related to one another (how a change in one component affected another component). Neither group received any procedural information. The group who got the diagram and explanatory text as well as rote instruction learned the procedures faster and more accurately, performed the procedures faster, and developed new, more efficient procedures more often than the group who got only rote instruction.

Kieras and Bovair believed the key to success was the ability of the diagram and text group to help learners develop a cognitive model of the device's operation so that procedures could be inferred. A follow-up experiment confirmed that this group's success was due to the explanations of how the components related to one another rather than the motivational aspects of the association with Star Trek, the description of power flow and how items were connected, or general design principles and rationale such as why a particular item was needed.

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 bicycle pumps, to build a cognitive model of the system. 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 (1977) and Wardle (1977, cited in Levie & Lentz, 1982) found that aptitude affected learning from multimedia. In the Blake (1977) 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 (1977, 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.

Conclusion

This examination of a wide variety of empirical studies shows that multimedia information helps people learn—sometimes. Computer-base multimedia appears to help people learn more information in less time than traditional classroom lectures. Information presented via redundant multimedia does not always improve learning compared to "monomedia" information.

Multimedia information appears to be most effective when:

- It encourages the dual coding of information
- The media clearly support one another
- The media help learners build cognitive models of the systems they are learning
- The media are presented to learners with low prior knowledge or aptitude in the domain being learned.

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