The Effectiveness of Educational Computer Graphics

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ABSTRACT

Although the computer is a fairly recent invention, it has been integrated extensively into most areas of business and personal activities. Most recently, extensive application of computer graphics and computer animation have been incorporated in the educational realm. This research provides a comprehensive look at the effectiveness of computer graphics in educational materials. Available research and theories relating to traditional visual aids are applied to computer graphics and combined with current research on computer animation to review the applications and effectiveness of computer graphics in education. Topics such as motivation, interactivity, and novelty are also discussed as they relate to computer graphics. It is concluded that the effectiveness of computer graphics in education can be valuable, but is limited. More research is necessary, especially in relation to motivation and computer animation due to the rapid expansion of the technologies and the quantitative/qualitative growth in educational materials available in the classroom.

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OUTLINE

INTRODUCTION

When the computer was introduced to the public in the late 1970s, it was revolutionary. It has had an amazing effect on American society. Limited at first, computer applications have grown steadily and seem bounded only by the imagination of the humans that use them. The computer revolution may turn out to be more "significant than any other technological advance in the last 200 years" (Lepper, 1985, p. 1). This will have, and has had, a profound effect on education. It has been predicted that by the year 2000, most of our children's education will involve a computer (Bork, 1980; Kleiman, 1984; Papert, 1980).

With less than two decades of experience, it would seem that there is very little research to support the use of computers in education. Also, because of the unprecedented rate of growth in this area, much of the research available is out of date or is quickly becoming so. This is even more evident in the area of computer graphics. Just within the last few years, computer hardware and software have been manufactured that are capable of handling graphics and animation that can compare with video games. Unfortunately, it still seems that entertainment is always technologically several steps ahead of education.

Educators around the country seem to be jumping at the chance to use the newest computer technology their schools can afford. As the prices for computer software and hardware continue to fall into the range of educational budgets, and as parents continue to pressure the schools for the 'best' education for their children (equating technology with quality), this trend will most likely continue.

My purpose in researching this topic is to discover if there truly is justification for the use of computers in education, and if so what. I will be focusing on computer graphics and animation, an important subset of graphics, since these are the most recent and becoming the most popular applications of computers for educational purposes.

HYPOTHESIS

My hypothesis is that there *is* justification for the use of computer graphics in education, including computer animation, as an effective instructional tool. Their effectiveness, based on research, however, may be very limited. I do not know whether research can keep up with the rapid advances in the computer industry. The scope of research material may not include the most recent developments in educational computer tools. The price of computer related materials often limits the technological level at which research can be conducted. This can lead to outdated research that may not apply directly to present educational technology standards, but can provide important principles and guidelines for educational materials.

I also think that the motivational potential and novelty effects of computer graphics will play an important role in deciding their effectiveness. Children are usually drawn to new and exciting things. If computer graphics can be new and exciting, they may prove to be very beneficial. Gaining a student's attention is one of the most difficult things an educator faces today. When thirty second bits of information and thirty minute excerpts of 'life' are the standard for children's attention span, the task of attracting interest and keeping that interest can become an immense challenge for educators. I may find that the novelty effects of computers can be valuable, or I may find that interest is achieved not through the use of computers, but through creative lessons, no matter what the medium.

Also, the interactive capabilities of computer graphics may allow education to be much more personalized. Educators may no longer be faced with the dilemma of teaching above one student's level and below another's for the benefit of the class as a whole. If computer programs can be developed that can discern differences in student ability level and discover which learning techniques work best for individual students, the individual education of each student may be improved far above what it is now. For example, during a physics lesson, one student may not need much time to see that something with more mass takes a greater force to move the same distance as something with less mass, but another might. The second student, while struggling in physics, may not need to dwell on geometric principles while the first one does. Instead of general lessons that seek to ensure learning for the majority, or average students, educators could oversee the use of interactive computer programs that provide each student the opportunity to work up to his or her individual potential.

I also think that my research will determine that more research needs to be conducted. I feel that although quite a bit of the research involving visual aids can easily be applied to computer graphics, much of it is outdated and unrealistic. Experiments involving simple geometric, line drawn graphics displayed on a monochromatic screen do not compare with the endless possibilities of realistic looking, quality graphics becoming more and more accessible each year. I think that I will discover that new studies need to be conducted building on the past research, but incorporating the most modern educational technology available. Also, I think that realism, color, and especially the changing motivational power, novelty effects, and interactive capabilities of computer graphics and computer animation will become increasingly important research topics in the years to come.

COST

A factor often considered when dealing with computer utilization in an educational setting is cost. However, cost will not be a major factor in this research as it is not consistent to any one use and is becoming less of a factor almost daily. Computer hardware and software prices are declining at a phenomenal rate. Between 1983 and 1987, the cost of microcomputers fell about 50% (Levin, Glass, & Meister, 1987). If automobile efficiency and technology had progressed at a rate similar to that of computers, a Rolls-Royce would cost less than $3.00, get almost 3,000,000 miles to the gallon, and have enough power to pull an aircraft carrier (Lepper, 1985).

Cost will *always* be an important issue to educators, but the economics of having computers changes frequently. The most important issues revolve around the viability of computers and computer graphics as educational resources. Educators will need to compare the available research on the effectiveness of computers with the cost and how that fits within the individual budget of the school at the time. I do not believe that much research based on the cost effectiveness of using computers can have widespread, lasting application because the cost of computer-related resources changes so much.

One point to note, however, is that hardware costs represented only about 11% of the cost of implementing computer aided design in a school (Levin, Glass, & Meister, 1987). Even if hardware costs do drop dramatically, other factors such as software, training, and facilities will have as much or more of an impact on overall cost than the actual computers.

VISUAL PROCESSES

Educators, for the most part, are under the impression that visuals help in teaching information to students. The use of the term visual aid automatically presumes that such utilization is in fact an aid. Several related theories of visual processes are presented: the dual coding theory, the contiguity principle, the multiple channel theory, and the single channel theory.

S. J. Samuels was one of the first to question the widespread acceptance of visuals as an effective learning tool. His studies focused on the use of pictures to teach reading. In one study he found that using pictures resulted in more correct answers while actually learning the word, but when tested on the word without the picture later, the students who had learned without the picture scored higher (Samuels, 1967). His summary of several studies (Fowler, 1962; Harris, 1967; Braun, 1969) showed that learning vocabulary by sight was improved when no picture was used to compliment the word as compared to the same words paired with pictures. The pictures were thus distracting and drew attention away from the word. Samuels credited this to the "principle of least effort" (1970, p. 400). If a student is given a choice of stimuli to produce a desired response, the student will focus on the one that produces the desired response in the easiest manner, for the student. Therefore, when confronted with a word and a picture, the student may choose to focus on the picture and may, in the process, ignore the word.

These studies focused solely on retention, but as far as comprehension is concerned, Samuels (1970) found similar results. In reviewing several studies on the effects of pictures on comprehension of information (Weintraub, 1960; Koenke, 1968; Lindseth, 1969) he found that students who were shown pictures did not comprehend the corresponding information any better than those who were not shown pictures and sometimes were worse.

Dual Coding Theory

As described by Paivio (1978), the basis for the dual coding theory is that there are two separate systems involved in perception, memory, language, and thought. One system involves nonverbal processing and is referred to as the imagery or visual system. The other processes information such as speech and language. This is referred to as the verbal processing system.

Consequently, there are two ways of perceiving complex information: visually and verbally (Paivio, 1978). For instance, the verbal processing system would store an object by its name and would later retrieve it from memory by that name. The imagery system would store and retrieve the same object by its physical characteristics such as size, shape, or color. The verbal system is specialized in communication while the imagery system is specialized in processing environmental information (Paivio, 1978).

The two systems can work independently, as when you are driving and listening to the radio at the same time. Your imagery system is noting the environmental stimuli that affect your driving, while your verbal system is concentrating on the aural information coming from the radio. Part of the reason this works is that you are also processing information in two different modes: by sight and by hearing.

Brooks (1967) warned that interference occurs when the same mode is used to try and process information in both a verbal and nonverbal manner. For instance, it was found to be difficult to read about a spatial relationship and visualize that relationship at the same time because both utilized the visual mode. Alternately, it was found that when the relationship was described orally, the subjects had no problem listening to a description of the relationship (verbal mode) and visualizing it (visual mode) at the same time.

Although the visual and verbal systems do have a certain degree of independence in processing information, the two systems cannot work entirely independent of one another. The two systems may have to call on each other in order to fully process information. When describing a physical object to someone, you will usually call on the imagery system to get a visual image of the object and then use the verbal system to describe the object with words. In fact, Paivio (1978) described the connection between the nonverbal image of an object and its name to be the strongest or most direct connection between the imagery and verbal systems.

The application of this theory is that students are much more likely to remember something, and be able to retrieve that information from memory later, if there are two mental representations of the information: verbal and visual. That way, if one of these representations is forgotten, the other will remain and can be called upon by the student (Rieber & Kini, 1991).

Based on these assumptions, it was concluded that the same processes used for perceiving information were also used for storing and retrieving it. This contrasted sharply with previous theories (Anderson & Bower, 1973; Norman & Rumelhart, 1975) which proposed that perceptual information was converted to an abstract form in long-term memory.

Paivio (1978) argued that if the previous theories were correct, there would be no difference in reaction time to a picture or word describing the same object because both would need to be converted to the same abstract form in memory. He performed several experiments involving comparisons of objects by pictures or just written words. He found that the reaction time in differentiating the size of an object based on a picture of that object was significantly (around .25 seconds) less than when words were used to describe the object. These experiments offered credibility to the dual coding theory and drew substantial support.

Today, educators use the dual coding theory as a defense for using visual aids. It is assumed that visual aids assist in storing information in both the verbal and visual systems. This redundant storage of information acts as insurance in case one system loses the information (Rieber, 1989). But, for dual coding to occur, the information being presented must be "highly imageable." Supportive research revealed that information that is highly imageable has a better chance of being remembered because there is a better chance that dual coding will occur (Rieber & Kini, 1991, p.85).

Contiguity Principle

The contiguity principle, based on the dual coding theory, states that multimedia instructional tools are more effective when words and pictures are presented at the same time. Mayer and Anderson (1992) found support for their theory in several experiments comparing contiguous and noncontiguous pairing of printed words and narration with graphics or animations of the information to be learned. They found that when the words or narration were separated from the pictures or animation, respectively, the construction of referential connections that were necessary for problem-solving activities was hindered.

The dual coding theory and contiguity principle suggest that meaningful learning, in the form of problem solving, is a result of students being encouraged to make connections between visual and verbal representations. The best way to do this is to present the words and visuals contiguously in time or space (Mayer & Anderson, 1992). Computer graphics and specifically computer animation can be an effective implementation of contiguous presentation.

Multiple Channel Theory

The multiple channel theory is based on presenting information to one or more channels (sight, sound, etc.) at the same time. This helps the student organize the information better and therefore should increase learning (Dwyer, 1978). It is also believed that if a lesson is presented to several different channels, the chances are higher that the student will interact with the information being taught in at least one way. This gives the student the opportunity to interact with the lesson using the channel they prefer.

Hartman stated that "redundant information simultaneously presented by the audio and print[visual] channels is more effective in producing learning than is the same information in either channel alone" (1961, p.42). There is a large body of research that supports this finding in that evidence of learning is greater when multiple channels are presented with the same information as compared to only one channel (Day & Beach, 1950; Hoban & Van Ormer, 1950; see Dwyer, 1978, p.24 for a more complete listing).

These theories, with empirical support and widespread acceptance, lead many educators to believe that as a rule, visual aids increase learning. Unfortunately, this may not always be the case. With the availability of computers to produce high quality visuals, multimedia presentations, and animations, teachers may be tempted to spend too much time fiddling with technological gadgetry, and not enough on the educational goals of their lessons. Obviously, this is not always the case, but it is something that should be guarded against.

Single Channel Theory

Another theory called the single channel theory is based on the fact that there are limits to the amount of information a student can process. When encountering new information, the student's ability to discriminate between relevant and irrelevant information is decreased. Also, the more stimuli presented in a lesson, the more processing the student has to perform. This can slow down processing rates and increase the potential for error in isolating the relevant information in a lesson (Dwyer, 1978).

Humans code sensory information as it is received. This basically means that we retain information our sensory system deems important and ignore the rest. This enables us to organize stimuli into groups that are more meaningful and from which we can draw conclusions and make some sort of response (Dwyer, 1978). If an educational lesson can simplify this process for the student by organizing the information and limiting the amount presented, the learning process will be faster. If information is only presented to a single channel, the student does not have to decide which channel to utilize and the chance of disregarding important information is much less.

This does not necessarily contradict the multiple channel theory, but it does put a theoretical bound on the amount of external stimuli that is valuable for teaching. Therefore, educators must be very careful in deciding on visual aids. Unless the information presented in the aid reinforces or presents a relevant point of the lesson it is just another element that the student will have to spend time processing. Even if it is directly relevant to the lesson, it may add too much stimuli and the difficulty lies in the amount of the external information the student must process (Dwyer, 1978).

AESTHETIC ATTRIBUTES

Two important issues related to computer graphics that have gone relatively unresearched are color and realism. There is a lot of speculation as to the importance of these properties, especially now with the common availability of millions and millions of colors and the almost photorealistic capabilities of computer animation.

Color

One of the things that an educator may fail to realize is the effect colors can have on learning. Color may sometimes be dismissed as an afterthought and dismally cause a lesson to fail in attaining its full potential as an educational and motivational tool. At the opposite end of the spectrum is the teacher who feels compelled to use every color available causing the visuals to become muddied and confusing.

Whether meant simply to entertain, inform or educate, computer graphics can be described as an artistic form of expression. Just like the artist, the educator utilizing computer graphics is trying to make some kind of impression or convey certain meaning through the work. For centuries, the primary method that artists have been using to accomplish this has been through the use of color (Faiola & DeBloois, 1988). It seems that sometimes educators may forget the importance of color. It may be a lack of understanding. It may be the medium. Maybe those developing computer graphics do not associate it with 'art' and certainly even less with 'high art.' I feel that this is an extremely important point: a computer graphic is art, and therefore succumbs to the same rules as far as color and composition are concerned.

I do not mean to say that color is the most important factor, but it requires more emphasis than in the past, especially with the growing possibilities offered through modern software and monitors. Color needs to be a concern throughout the design of educational visual aids. It should be a priority for educators and implemented so that the student does not even have to think about it, unless, of course, the lesson is on color. Color should be used in such a way that important aspects of the lesson naturally gather students' attention while background information remains neutral.

In order to give a two dimensional painting three dimensional qualities, artists will use a variety of perspective tricks. One of those tricks is based on the fact that we perceive cooler, duller colors as being farther away than the warmer, brighter colors. Therefore, a good choice for background colors are the cool colors such as dull blues, greens, and grays. Foreground colors should be warmer and brighter, such as oranges, yellows, and reds. This is an easy guideline to implement that will give computer graphics more depth. The opposite (warm, bright colors for backgrounds and cool, dull colors for foreground material) can have extremely detrimental effects. This will confuse the student and increase the difficulty of spatially differentiating objects on the screen.

Dwyer (1978) reported that several studies have been done with regard to the emotional and physiological responses that color can create (Goldstein, 1942; Kouwer, 1949; Rudisill, 1952; Collier, 1957; Smith, 1958; Birren, 1959; Schwartz, 1960). Color can easily be associated with good or bad images and can cause emotional and aesthetic reactions. One study revealed that viewers who watched color television programs were much more emotional in their written response to the program than those who watched the same program in black and white (Scanlon, 1970a, 1970b). This suggests that using color visuals in an educational setting can evoke more emotion for or about a particular lesson than just black and white.

CONTRAST. One of the most important aspects of color is contrast. For students to be able to easily differentiate objects from one another or from the background they must contrast each other. This is even more important than the actual colors chosen. Because colors will vary slightly from screen to screen, the best way to ensure portability of lessons involving computer graphics is to depend more on contrast and general hues than to spend much time deciding between slightly different colors.

The eye can distinguish between millions of different colors. However, the untrained eye can only keep track of a few, depending on the complexity of the design. Those who have used computers for a longer period of time are able to perceive and respond to a wider range of colors. Beginning with a limited number of colors is generally a good idea when integrating computer graphics into the classroom (Faiola & DeBloois, 1988).

Contrast is especially important when text is concerned. Text should either be dark on light or light on dark. There should be enough contrast so that the text is easily readable. You do not want a student to lose interest right at the beginning because of eyestrain or difficulty in reading. Focusing on contrast also deals with the problem some students have in remembering colors and makes programs more accessible to color blind students (Faiola & DeBloois, 1988).

CONSISTENCY. One of the most crucial objectives in developing an educational computer program is consistency. If the NEXT button is green, make it green on every screen. If the HELP button is yellow keep it yellow (Faiola & DeBloois, 1988). The student will feel much more confident and comfortable with the program and be able to attune to the actual lesson material if they do not have to worry about where to find the HELP button because it has moved and is a different color. This is one of the fundamental reasons why windows based software is so popular. Any user that is familiar with Windows can go to any computer and quickly identify the PRINT icon, the justification settings, or any number of other functions, and is comfortable with the familiar layout because the programs are consistent. Consistency cannot be stressed enough, especially when developing programs for educational use and even more importantly for elementary level students.

Another thing to consider is consistency with the outside world. Use colors to indicate ideas that they already convey. For instance, use red to indicate when to stop. Use yellow to indicate a warning. Use green to indicate when to begin or to proceed. Use blue to indicate cold. This use of color is obviously subject to cultural, social, and regional considerations, but the point is to attach meaning to objects through the use of color and use colors in a way that is familiar to the students (Faiola and DeBloois, 1988).

Realism

LIMITING REALISM. Another relevant issue in implementing computer graphics and animation is realism. Intuitively, it would seem that the more realistic the graphic material, the easier it would be for students to identify with what is going on and therefore increase learning. However, too much realism may be confusing. The real world may have much more sensory information than you would want in a lesson at one time. If the picture is too real, the student may be unable to discern between periphery information and that which is central to the lesson. Instead of focusing on the pertinent information, the student may scan the entire image, not really concentrating on any particular part (Dwyer, 1978).

Another reason to limit realism is the fact that the brain does the same thing. The brain takes in sensory information from the world and then simplifies it. The nervous system cannot handle the amount of information that is available. If the educator can simplify visual material, then the student does not have to. Simplified visuals result in less distraction and reduce the chance of the brain shifting its focus toward peripheral aspects of the lesson while losing the important information (Travers, 1964).

Conversely, if a visual has too little sensory information, the student is limited by the capacity of the visual. No matter how long the student is allowed to look at the visual, there is only so much information that can be processed (Dwyer, 1978).

REALISM CONTINUUM. Research has developed a realism continuum for static visuals that finds the most efficient form of illustrations for learning in between photorealistic images and simple line drawings (Dwyer, 1978). Starting at the low end are simple black and white line drawings, then color line drawings, detailed, shaded black and white drawings, detailed, shaded color drawings, black and white photographs of a model, color photographs of a model, realistic black and white photographs, and color photographs being on the high end (Dwyer, 1978). Although these speak for general visual aids and do not include computer animation, a similar scale can be applied to animation. The low end would include black and white stick figure animations, then color stick figures, then detailed and shaded black and white animations, color animations, three dimensionally modeled black and white animations, three dimensional color animations and finally black and white and color live video. The most effective visuals are usually in the middle of the realism continuum, but vary depending on the subject matter and objectives of the lesson. Interestingly enough, words, whether spoken or written are the lowest form of realism because they in no way physically represent the objects they describe (Dwyer, 1978).

Although very little, if any, research has been done on the realism continuum as it relates to computer animation, it can be assumed that some of the general principles regarding still visuals can be extended to animation until research can be advanced in this area.

INTERACTIVITY

One of the great advantages of using computers as a learning tool is the interactive possibilities. The major benefit of an interactive computer program is that it "gives the student immediate feedback and makes learning more interesting and enjoyable" (Wilson, 1993, p. 30). Allowing a student to set his or her own pace in learning can be valuable. The computer can help the student to focus on areas which may be difficult, but which may not be difficult for the rest of the class. This enables the student to have individual attention given to his or her learning ability, level, pace, and use of graphics.

Learner-Control vs. Program-Control

The assumption of interactive learning is that students are the best at judging their own needs and abilities as learners. Lee and Lee (1991) tested this hypothesis by examining the differences, between learner-control and program-control methods for solving chemistry problems in high school. Learner-control means that the student makes the decisions as to examples, sequence, pace, and practice. These decisions do not necessarily have to be conscious, but can be a result of the student's input. For example, the computer may present a difficult problem after a correct answer or an easier problem after an incorrect answer. Program-control means that the computer makes these decisions independent of the student. This is usually a program where every student experiences the exact same set of problems or activities in the same order.

Lee and Lee (1991) found that learner-control methods produced poor achievement academically because improper choices by the learner can sometimes cause the program to end earlier than necessary. However, in their review of a study conducted by Lee and Wong (1989), it was found that even when the learner-control group worked longer at the computer than the program-control group, the program-control group performed better. In this study, the subjects had low prior knowledge of chemistry, and in a study by Gay (1986), the low prior knowledge students performed better using program-control strategies while higher prior knowledge students performed the same in both strategies. A student with no prior knowledge of the subject can hardly begin to monitor his or her own progress. It is still unclear why prior knowledge students did not perform better using the learner-control method.

Lee and Lee (1991) contended that the learner cannot be the best judge of his or her own needs and abilities unless two criteria are met: the student must know his or her own mental capabilities and have some skill related to the lesson to be learned. In testing this hypothesis it was discovered that learner-control methods are efficient, but depend on the student's previous knowledge of the subject. Learner-control methods are much better than program-control for the review of recently attained information, but there is little difference between the two when there is a high level of prior knowledge. Program-control, however, is much better for acquiring information when there is a low level of prior knowledge, but makes little difference when there is a high level of prior knowledge.

This means that the effectiveness of interactive programs depends a great deal on the knowledge base of the target students. The most likely conclusion is that neither isolated strategy is best, but the integration of the two in producing a program that allows for some leeway in making learner-controlled decisions while limiting some of that decision making is best. This study probably caused more confusion than it resolved, but the important result is that it challenged the popular opinion that interactive programs are great because they allow the students to judge themselves (Lee & Lee, 1991).

Pace

Animation can play an important part in interactive programs. Animation itself is an interactive process. The movement involved in computer animation causes constant change in what is being presented. The viewer must constantly adapt to these changes and constantly evaluate what they are seeing. "This process makes them active learners" (Wilson, 1993, p. 30), but also requires more processing, which may cause some students to miss some of what is being presented.

Rieber (1989) found that students attended to the information in a more accurate manner when computer animated graphics were supplemented with interactive instructions forcing students to focus on information contained within the visual. He used a method by which the screen is broken down into "chunks" (p. 11). Only part of the screen is revealed at any one time. The student must press a button or key to reveal other parts of the screen systematically. This increases the likelihood of students attending to all of the important parts of the visual instead of just viewing it as a whole and moving on, perhaps missing some important details. The results of this study revealed that using computer animated graphics in this manner were more effective than either still visuals or none at all.

Alternately, interactive computer programs can defeat themselves if the pace is too slow. It is arguable that interactive programs allow students to work at a level that falls short of that which could be attained if the program had more structure (Lepper, 1985). Computer programs may have some leniency in the pace and level at which they teach, but there must be some limitations as to how long they will allow a child to flounder with the same subject. "Highly interactive computer programs do not guarantee that students will be engaged at a sufficiently deep level for meaningful learning to take place." (Hennessy & O'Shea, 1993, p. 131)

Reality Conflicts

A good interactive program can force a student to deal explicitly with their own beliefs about natural phenomena or scientific principles. It allows students to explore their own rationalization techniques about abstract principles and immediately see the results of their rationale. Students cannot explore their own beliefs about the manner in which the real world works unless they are allowed to interactively do it for themselves (Hennessy & O'Shea, 1993).

This does not always work, however. Sometimes, when there is a conflict between the student's preconceived idea of how something should work and the computer's explanation of how it really works, the student may believe that the computer is not accurately simulating the real world and is therefore untrustworthy, or 'magical'. However, if the student realizes that they are manipulating reality and applying physical forces that do not occur in real life, it can be a valuable experience in exploring the way physical properties work (Hennessy & O'Shea, 1993). By seeing what would happen if gravity or friction did not work the way they do, it can reinforce the knowledge of how they really work.

Hennessy and O'Shea (1993) suggested that teachers be clear about the reasoning for using computers or even in traditional laboratory experiments why an event is being isolated from reality. The difference between the experiment or simulation and reality must be sufficiently explained. More importantly, the teacher must explain why this is being done. Then the student will be better equipped to accept the principles of the experiment.

It can also be dangerous to isolate the computer from the real world because an error that would occur in the real world may not be encountered in the computer. The student may not learn how to deal with that error or even that the possibility for error may exist (McDermott, 1990). These issues give more credence to the fact that human teachers are still very necessary. Because students may not trust the computer and may believe it to be magic, it is up to the teacher to emphasize when the computer is adhering to physical laws or other real world phenomena and when it is isolating variables and creating stylized environments.

Hennessy and O'Shea (1993) determined that even if the instructions are well written and informative, the student cannot be left to his or her own devices in front of a computer. This can lead to reinforcement of incorrect perceptions. The computer, and the teacher, should allow the student to experiment and confront reality as compared to his or her own perception of how things work, but intervention and direction provided by the teacher is a must if the student is to fully realize the benefit of the computer simulation and the limits of his or her own perceptions. There must be a trade off between the abstraction and isolation of variables that a computer program can offer and the complexity of a real world simulation (Hennessy & O'Shea, 1993).

Research

Collins, Adams, and Pew (1978) found that when a student responded incorrectly and the computer elaborated on the subject for them, test scores were higher than when there was no elaboration. This indicates that interaction with the student and response to specific needs of individual students can be beneficial to learning. This study was conducted almost twenty years ago and shows an excellent use of interactive technology.

Farnsworth (1995) found that veterinary students using interactive programs to simulate the diagnosis of an unhealthy animal showed marked improvement in their future diagnoses than students who used the written notes of the professor. He found interactive simulations to be a good compromise between highly efficient verbal presentation and highly effective hands on methods. Control over the graphics by the student in this context provided positive results.

Involving students in the problem solving aspects available through interactive computer programs can be extremely valuable. The Cognition and Technology Group at Vanderbilt (1993) found that when students learned information through problem solving, they could remember and spontaneously recall the information in new contexts better than students who had been taught the information with the goal of remembering it. The problem solving method better enabled students to plan and use the information in new situations.

Rieber (1989), based on his work with interactive animated graphics, concluded that "any purposeful interactivity aids learning more than no interactivity" (p. 30). He encouraged the continued use of interactive graphics as being well worth the time required to produce them.

Feedback

STUDENT. An interactive computer should be flexible and react to the actions of the student the way a human teacher would (Collins, Adams, & Pew, 1978). An interactive program should be able to read the student and adapt accordingly. If the student consistently chooses certain methods of learning and continues to do well, the program should react and structure the lesson in a way that suits the student. If the student continually chooses some method, but is not learning at a sufficient level or pace, the program should divert the student's attention toward other methods until one is found that works for the student and then incorporate this method with the method the child prefers.

For this to occur, computers are going to need to be able to recognize individual students. Although this process would be an ongoing one, after the initial evaluation of each student, only minor changes should need to be made. Such continual recognition of a student and his or her changing ability and interests requires networking and increased computer memory, both of which are becoming increasingly accessible.

EDUCATOR. Another benefit of interactive computer animation is the instantaneous nature of feedback and the type of feedback available. This allows the educator to see immediately whether or not the students are understanding the subject matter. The educator is no longer confined to the tediousness of constantly hand-grading assignments. "The opportunity to learn how a student copes with conceptual content of a subject without the encumbrance of calculational tedium is a valuable one" (Schwartz, 1970, p. 35). She or he can quickly see how well a lesson is working and modify it accordingly. Also, factors such as response time and comparisons with other students, classes, cities, etc. are much easier.

Once a program is designed, unless it has major theoretical problems, minor changes and improvements of the design are pretty simple (Zavotka, 1987). Even if it is working well on a majority of the students, the educator can see who is having problems and react. The time saved by not having to spend entire evenings grading papers can be spent on improving lessons and also on relaxing, something that will improve an educator's attitude which will no doubt reflect well on the students.

MOTIVATION

One of the most compelling aspects that attracts educators to computer graphics and animation is their influence on motivation.

It can become very easy for an educator to be enthralled with the flashy results of computer graphics. It can be very satisfying to produce an advanced educational graphic that gets immediate results in the form of heightened attention and perceived motivation in the students. First of all, the mere fact of being able to work with a computer and make it perform as desired can be very rewarding. Second, when an educator gets a wonderful reaction and response from the class, there is a high degree of motivation for the educator to continue in that vain.

This can get dangerous. Without being specifically designed to support the lesson and without empirical support, computer graphics will more than likely be ineffective instructionally, and may even detract from the possible educational potential of the lesson.

For example, a program might be designed to teach the effects of different forces on objects of different mass. The object of this program might be for the student to apply forces to different objects on a frictionless table, but keep them from falling off. If the consequence for applying the wrong force or applying it in the wrong direction was that the object splattered to the ground, the student might take pleasure in failing just to watch the objects fall to the ground. This would then be reinforcing the wrong responses by the student.

Computer graphics may gain the student's attention, but it may not be directing that attention to the proper information. An increase in attention provides no educational benefit unless the student is attending to instructional information. All of the flashy 'bells and whistles' that are used to attract and motivate can block students' attention to the important elements of the lesson material (Fitzgerald, Fick, & Milich, 1986). Motivation simply for motivation's sake should be guarded against. There are several arguments for and against the motivational use of computer animation that should be taken into consideration.

Research

"Studies have determined that students do learn from computer-based instruction, and that students find computers to be motivational" (Kinzer, Sherwood & Loofbourrow, 1989, p. 41; Brown, 1986; Zuk, 1986).

Rieber (1989) indicated that using computer animation to get the attention of students is a practical application and that it can be used effectively to gain student's attention and to keep that attention throughout the lesson. He warned, however, that a lot of this has to do with the novelty of computers. "As novelty effects decline it cannot be taken for granted that computers will serve as a superior learning tool" (Kinzer, Sherwood & Loofbourrow, 1989, pg.47). Rieber (1989) also warned that the long-term effects of the motivational power of computer animation have very little empirical basis.

One of the areas of computer graphics that seems to have the greatest motivational power is computer games. Klein (1991) stated that instructional games increase performance and motivation because games create enthusiasm, excitement and an enjoyment of learning. They achieve this because students are required to be actively involved in the learning process. Some studies have shown increased interest, satisfaction and motivation, but Wolfe (1985) argued that not enough research has been conducted to examine an instructional game's motivational power or even what kind of student is motivated by the use of games.

Klein (1991) found that college students found an instructional game used to review educational psychology motivating as compared to more traditional review practices. However, the results showed that the game did not increase performance.

Rieber (1991) found that elementary students overwhelmingly preferred a spaceship computer activity over a word search puzzle or a questioning activity. He found that they preferred the word search over the questioning, which was on computer. This led to the conclusion that the computer itself is not necessarily motivating, but the motivation lies in the nature of the activity. His study did provide, however, evidence that supports the theory that certain computer activities are intrinsically motivating to elementary students.

Guidelines

Lepper (1985) proposed several factors that effect motivation.

The first is that humans are problem solvers. Goals should be clear, have an adequate difficulty level, and be based on the students ability to reach the goal rather than luck. The second is that people are naturally curious and like surprise. Programs should involve novelty, variability, and uncertainty. Third, humans like control. If a program involves a high degree of user freedom, or if the user perceives this to be the case, it should increase motivation. More research is necessary to determine which has empirical support and which is best in determining actual motivation, or the more likely conclusion that all three factors effect motivation.

DIFFICULTY LEVEL. One thing that is generally accepted as a motivating factor is difficulty level. Children like tasks that are not extremely difficult, but challenge them to a certain extent (Lepper, 1985). There are several things to be aware of, though, when making a program difficult. First of all, the software is going to have to be able to adapt and become increasingly difficult as the student increases in ability. Second, the student must be informed that the level of difficulty is increasing. If the student cannot perceive the increase in difficulty, he or she will think that his or her performance is not increasing because of relatively similar scores on increasingly difficult tasks (Lepper, 1985).

Rieber (1989) contended that if an activity seems challenging, but the student believes he or she can control it, then the activity is intrinsically motivating. Based on his research, he concluded that some computer activities do contain a level of intrinsically motivating factors for younger students.

SCREEN QUALITY. Another motivator is screen quality. Screen quality has been connected with strong improvements in performance if it can hold the interest of the student and reduce confusion, eye strain, and fatigue (Faiola and DeBloois, 1988). Once the student is attracted to the computer, making the program flow and easy to follow and making it easy for the eyes to digest can aid in keeping the student's attention and keeping them motivated.

Need For More Research

One of the major concerns with using computer animation as a motivational tool is the lack of research on this subject. Concerns arise as to whether using computer animation as a motivational tool increases learning, has no effect, or is detrimental to learning. "We know very little about this very fundamental question of how motivation affects learning" (Lepper, 1985, p. 6). Because there are so many different reasons and ways to motivate students, it is hard to find comprehensive research that can determine the detrimental, beneficial, or neutral effects of motivational educational software.

Another thing that needs to be considered is the long term effects of using motivation as a tool for learning. There are several questions that need to be answered concerning the negative side of using motivational tactics. Will students continue to be interested in the same subjects when there is no computer to motivate them? When the flashy graphics and neat effects are gone, will the student's interest leave with it? Is motivational software really preparing student's for their future? Will students be able to cope with the transition into high school, and especially college, where little, if any, external motivation is offered for learning?

Another concern that has been grossly overlooked is the difference between boy's and girl's reactions to computer graphics, especially games. Lepper (1985) stated that boys participate in optional computer programming courses and educational game programs more than girls. Much of this can be attributed to the fact that 'educational' software is generated around themes and activities that are generally more appealing to boys. Many activities involve typically male preferred sports such as basketball, baseball and football (Lepper, 1985) and activities such as war, fighting, military involvement, and flying airplanes. Although it may seem sexist and would be incorrect to imply that these activities only appeal to or are suitable for males, they *are* generally more appealing to boys. If computer graphics are to be an acceptable form of educational material, the differences between what motivates boys and girls are going to have to be dealt with.

Arguments can be made for and against using computers to motivate students, but what is necessary is further research that can support a more scientific approach to this issue. If enough empirical support can be generated, indicating that computer animation and interactive lessons do contain intrinsically motivating factors, it is likely that students will stay attentive and work for lengthier periods of time because the motivation is being elicited from within the student. Internal motivation is what drives children on a daily basis to involve themselves in activities in which they are not required to participate (Rieber, 1991). If the computer can derive this kind of hobby-like interest it may prove to be an extremely effective educational tool.

There are a few additional positive issues, that if empirically supported, should encourage the widespread use of computer graphics as a motivational resource. Can computer graphics generate enough initial interest to spark an intrinsic interest in educational subjects that would otherwise be overlooked by students? Can computer graphics generate enough positive feelings toward learning that a general interest and desire for learning is integrated into a child's education at an early age?

Educator Motivation

Another motivational aspect of computer graphics and animation is directed towards motivating those interested in becoming educators and sustaining the motivation of established educators.

Schwartz (1970) found that students who come in contact with the computer animated film facility at MIT and who involved themselves in programming, designing, and producing computer animated films showed a marked improvement in attitude toward teaching.

Educators are underpaid and overworked and there does not seem to be much hope of drastic improvement in this area in the near future. Anything that can be rewarding to the educator and can increase their interest in reaching students should be encouraged. Even if no improvement in learning or student motivation is empirically available or supported, if the computer graphics are not detracting from the educational development of the student, it may be wise to consider its value as a motivational factor for the educator.

COMPUTER ANIMATION

Although the field of computer animation is relatively new, especially in relation to the field of education, there is a body of research available dealing with the use of computer animation for educational purposes. This research is limited in several aspects. First of all it is limited by time. Since the recent advent of computer animation into the realm of education, there has not been enough time to do much widespread, in-depth research. By the time a study has been completed and reported, it may quickly become outdated because of the rapid growth of the field. Research done using simple shapes and lines in the animation cannot compare to the almost photorealistic graphics available on much of today's educational software. Also, because much of the research is performed by college and university faculty, the most readily available subjects are college students. This limits the amount of research regarding elementary aged students.

Despite these drawbacks, many of the principles and discoveries of these experiments can be generalized to current educational animation possibilities and possibly to future applications. Although education is presently behind the technological pace of commercial computer animation, its pace is quickening. Rieber (1989, p. 3) stated, "current learning and instructional theories should govern the design and evaluation of animated visuals in instruction." Thus, until there is an adequate body of research from which to draw conclusive empirical evidence for or against computer animation, we will have to depend on the research that exists and apply it in a scientific manner to the aspects of educational computer animation that correlate most readily.

Comparison With Static Visuals

One thing to remember when comparing animation with static visuals is that animation is not actual motion. Animation, even at the highest technological level is just drawing one picture, erasing it, and drawing another slightly different picture, over and over again. Therefore, animation is the *illusion* of motion. The mind perceives motion by filling in the spaces between pictures. This is called "apparent motion." The brain has to organize the amount of separate images that the visual system sees and does this by organizing all of the separate images into one moving object (Rieber & Kini, 1991, p. 84).

Animation can also help to reduce the amount of mental work the student would have to perform. If the lesson is on something involving motion, and the educator is using still graphics, the student has to visualize the motion. This increases the amount of mental processing that must be done in short-term memory and decreases the chance of storing it correctly in long-term memory (Rieber & Kini, 1991). If the motion is provided for them, then there is less chance that students will store the information incorrectly.

The use of computer animation plays on our natural ability to perceive and expect motion. We live in an extremely dynamic world where very little of what we do and learn is based purely on still information (Rieber & Kini, 1991). Even when things are static, humans will easily interpret motion. When watching a film, the majority of what you are seeing is black space in between frames. There is very little actual visual stimuli compared to the total time of the film. Nevertheless, the brain easily interprets this as motion. Animation is therefore a way to base instruction more firmly in a dynamic world.

Possible Applications

It is a natural assumption that animation would aid in any topic that required or benefitted from an external visual. The difference, however, is that animation introduces motion and time. Based on this, animation should aid if the lesson involves visualizing something over time and/or in a particular direction. Rieber (1991) predicted that unless computer animation was used for these specific cases, there would be no difference in learning between animation and still visual aids.

The Computer-Generated Film Facility of the Education Research Center at the Massachusetts Institute of Technology designed computer animated films based on processes that they are unable to demonstrate directly, such as harmonics, electric fields, or protein structures (Schwartz, 1970).

Another area that has seen positive results through the use of computer animation is working with handicapped children or those with learning disorders. Geoffrion and Bergeron (1977) found positive results in teaching severely mentally handicapped children to read by having the computer show short, simple animations at the direction of the student. This is an encouraging use of computer animation and could prove to be very effective in teaching students with similar difficulties in communicating.

Research

Thompson and Riding (1990) performed an experiment based on the theory that relevant drawn diagrams can help with the general understanding of a mathematical lesson. They theorized that an animated presentation of the same material should be even more effective because the student is receiving much more information. They tested their hypothesis on 11-14 year old students, using Pythagoras's theorem as the lesson. All groups had a diagram for their personal use. The control group saw no other illustrations. Another group saw the diagrams displayed on a computer, and the final group saw a continuous animation of the diagrams. It was found that there were significant differences between the three groups, with test scores highest in the animation group, then in the still computer display and lowest with no computer illustrations. The experiment was highly controlled for external variables so they were able to confidently determine that the animation was the cause of the improvement.

Kinzer, Sherwood, and Loofbourrow (1989) performed an experiment using predator/prey interaction and the food chain as the instructional information. Two groups of fifth graders were given the same instruction, in the same manner, except that for review, one group was shown a computer animated simulation and the other was given an expository text. Results of a multiple choice test and a test where the student was given a list of animals and had to fill in a food chain pyramid showed that students in the non-computer group scored higher on both tests than the students who were shown the computer simulation. This study, however, used computer simulation for the whole class instead of individually. This may account for some of the discrepancy with other studies.

Zavotka (1987) found that students became more adept at interpreting orthographic drawings after watching computer animations of objects moving and rotating. She also discovered that watching an object transform from a three dimensional view to a two dimensional view increased scores on an orthographic test and also on a test where the student was required to mentally rotate the object. She concluded that for teaching spatial skills, computer animation can be an effective tool. She also pointed out the usefulness of computer animation in researching visual communication in general.

Rieber (1989) conducted an experiment in which fourth and fifth graders were taught Newtonian principles using the computer. He found that students who were shown animated graphics performed significantly better on the posttest than those who were shown still graphics or who were not shown any graphics. The results of this study were said to be dependent on the fact that students were only shown part of the screen at a time. Therefore, their attention was focused on small parts of the lesson in an incremental fashion instead of seeing the whole screen all at once. This was thought to focus attention and reduce the chance of distraction.

Although Rieber's (1989) parallel study using computer animation to teach adults showed no significant differences between the scores of those who were shown animated, still, or no visuals, there was a difference in response time. Those who were shown animated visuals had a lower response time. This suggests that animation can help in reconstructing motion information in memory faster than other means of communication.

This study (Rieber, 1989), in comparison with the same study aimed at elementary children, showed that people become less dependent on external visual prompts as they get older because they become better able to produce mental images on their own.

Rieber and Kini (1991) concluded that visuals can help in learning, but there are other times when they are relatively indifferent and still others when visuals can be distracting and therefore detrimental. The goal of researchers and educators, then, is to be able to discern the effect animation is having on students and adjust it appropriately if necessary.

CONCLUSION

Research has led me to several conclusions. First, there are several instances where computer graphics and especially animation *are* effective tools for education. Second, there are even more instances where their effectiveness is uncertain. Third, whatever novelty effects computer graphics may have are dwindling. Fourth, the motivational effects of computer graphics are questionable. Finally, much more research needs to be conducted on computer graphics.

There are several instances where research supports the use of computer graphics. The use of static computer graphics should be governed by current guidelines for the use of static visual aids. For animated graphics, research points toward limiting their use to topics that can be more accurately displayed through animation than any other media. Research supports the use of computer animation for lessons that involve motion and especially when the motion is associated with a specific direction. It can also be beneficial to use computer animation when other means would be too expensive, such as explaining how things act in a vacuum. Another valuable use of computer animation is teaching things that involve another time or a different culture (Kinzer, Sherwood & Loofbourrow, 1989), like a walk through of the Vatican at different stages of its development or a visit to the mining camps of the early gold rush. Also supported is the use of computer animation to isolate variables (Hennessy & O'Shea, 1993). This is very convenient in physics lessons that require frictionless surfaces or the removal of the effects of gravity. Manipulation of variables and forces is much more accessible through computer animation than traditional methods.

Other than these limited applications, research does not presently support the wide-spread use of computer graphics for educational purposes. Other, more traditional methods should be employed until research reveals more conclusive evidence as to other uses of computer graphics. If used, great care should be exercised in designing educational graphics. The educator must continually monitor student progress, and guard against distraction effects and possible weakening of the lesson as a whole.

Whenever computer graphics are used, it is very important that they serve a definable purpose. The objectives of the lesson should always be considered first. Other methods of presenting the information should always be considered before deciding on computer graphics. The educator should <u>never</u> sit down at the computer and use the graphical capabilities as the basis for lesson development. The students' needs and the lesson objectives should always be the determining factors in deciding whether or not to use computer graphics (Rieber, 1989). The reasons for using computer graphics, especially animated graphics, should be very clear to the educator. Any discrepancies between the computer and the real world should be clearly explained to the students.

What minimal novelty effects computer graphics may have are not widely supported by research. The reason for this may be that the novelty effects of computers are wearing away and could soon disappear. Researchers, therefore, may see research of this topic futile and waning and dedicate most of their work to other, more pressing aspects of computer graphics.

Using computer graphics to motivate students also has very little empirical support. This stems from the fact that motivation is such a variable quality among students, changing with age, socioeconomic status, race, gender, and from generation to generation. It is also very difficult to isolate and test. Motivation continues to be a subject of much interest and should continue to be pursued, but presently, there is little empirical evidence to support the use of computer graphics as a motivational tool.

As predicted, much more research is needed in the area of educational computer graphics before specific, widespread guidelines for their use can be established. It would be ideal if manufacturers of educational software would bear the brunt of the work in discovering the effectiveness of their products, but this is not the case. Most of the research done by manufacturers is based on how well the product will sell and how popular it is. However unfortunate, this is to be expected in a capitalistic society. Therefore, those truly interested in the educational effects of computer graphics are going to have to continue to conduct the research.

ALLOWING THE EDUCATOR TO TEACH

Although experimental research is extremely valuable, I think that an important point has been overlooked: educators are hired professionals and should therefore be given a degree of freedom in choosing how to teach their students. Educators practice every day using their intuition and experience to guide their classroom decisions. Although research may not substantially support every situation in which an educator might use computer graphics does not mean the educator should not use them. The educator is a very necessary part of the educational process. He or she needs to be able to examine the student's reactions and then be allowed to react accordingly.

I agree that more research needs to be conducted, but educators are going to have to apply it as appropriate. No amount of research can account for every situation that an educator faces. We seem to focus excessively on the need for research and strict guidelines derived from researchers whose experiments are highly specialized and sometimes unrealistic. Much more emphasis needs to be placed on the educators who experience what is being researched on a daily basis and in a much more 'real' setting.

There are several questions that seem much more important, yet remain unanswered. How do students really feel about computer graphics? How do their parents feel? Do their children come home from school and talk positively about their computer work at school? Do they come home and complain about it? What are the educators' feelings toward computer graphics? Do they seem to have more positive attitudes about their work? Do they get excited about using computer graphics?

I was fortunate enough to attend the Fourth Annual Educational Technology Conference at Texas A&M University. I was able to talk to many educators of elementary school children. I found that overwhelmingly, educators were excited and interested in computer graphics. Those that I talked to said that their students loved working on the computers and looked forward to the days when they got to go to the computer lab. This is obviously not scientific evidence, but it comes from fairly reliable sources and does deserve some recognition.

I do not mean to say that scientific research should be abandoned, but I do think that some emphasis on the attitudes of those directly affected deserves some serious thought. My research led me to the conclusion that very little of the research is consistent. Most of it has some confounding variable that can be pointed out as a lack of credibility in the methodology. It also seems that any point of view can be supported by some research somewhere. Because computers and computer graphics are quickly becoming the norm in elementary schools, the research needs to focus on the effects computer graphics are presently inducing. Also, I think more consideration and credibility needs to be given to the students and educators opinions.

I would conversely like to encourage educators not to depend too heavily on computer graphics. If computer graphics are used for everything, they are going to get boring for the student very fast and lose any novelty effects they may possess. Try to think of ways to keep lessons new and exciting, not just new ways to use the computer. As the computer is introduced in the classroom, more traditional methods of learning may gain new status as a welcomed break from the computer. But, if computer graphics seem the best medium to use in certain instances, then use them.

Emphasis needs to be focused on the objectives of the lesson and the goal of teaching for comprehension. Computer graphics should be viewed as one among many methods to choose from in furthering the achievement of that goal.

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