*Information Technology in Childhood Education Annual* (2002), 45-60

# Children Learning from Artfully Designed, Three-Dimensional Computer Animation

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An artfully designed, 3-D computer-generated video story was created to demonstrate the mixing of primary colors to obtain secondary colors. Two research questions were explored in this research: Do artfully designed 3-D computer-generated video stories enhance learning or are such entertaining works a distraction from learning? And, do children attend to the content of artfully designed video or are they merely entertained? Results of this study showed that visualization technology and the use of 3-D graphics stories can be employed in the field of art education to increases a child's understanding and attention to color theory. These findings contribute to theory regarding children's art education and provide evidence that 3-D computer-animated video stories can be valuable teaching tools for young children.

## BACKGROUND AND OBJECTIVES

Part of an educator's responsibility is to explain phenomena to learners. Because most learners gather the majority of the information that they learn through their eyes, educators need to provide a rich, visual environment in which to learn. In his book, (*Visual Explanations*), Tufte (1997) describes design strategies for creating visuals for students that "enhance the richness, complexity, resolution, dimensionality, and clarity of the content" (p. 10). Well designed visuals can provide explanations to learners that help them encode and retain content in memory as well as retrieve it for application (Wileman, 1993). Visual representations of data, procedures, and concepts can clarify meaning for learners.

Technology tools are making production of instructional visuals easier and less expensive. Therefore, visuals produced by both professional instructional designers and teachers are increasingly available. In fact, the vast array of visual stimuli in and out of schools brings into question the adoption of instructional videos by teachers. Educators, sociologists, and cognitive psychologists alike express concern about the impact media are having on children's development, well being, and thinking. Wartella and Jennings (2000) proclaim that "research on the effects of exposure to various types of content has taken on a new sense of urgency" (p. 31) in this media driven age. Postman (1995) expresses concern that technologies threaten our ability to contribute positively to the human narratives of stewardship of the Earth, spirituality, democracy, diversity, and language. And, Healy (1990) expresses concern that video "induces neural passivity and reduces 'stick-to-it-iveness'…. And may have a hypnotic, and possibly neurologically addictive, effect on the brain by changing the frequency of its electrical impulses in ways that block mental processing" (p. 199).

Such legitimate concerns call for evaluation of visual materials and research investigating the impact of video on learning. Rieber (1994) developed a useful principle that he calls "the first principle of instructional graphics": "There are times when pictures can aid learning, times when pictures do not aid learning but do no harm, and times when pictures do not aid learning and are distracting" (p. 3). When attempting to promote learning with a graphic, including animated video, we would do well to categorize that graphic in one of the three categories described by Rieber's principle. It is certainly worthwhile to determine whether or not video that is intended to instruct, does instruct, or if that video distracts from learning.

When animations are artfully created and placed in the context of a story, students may learn about color theory or they may become so involved in the entertaining aspects of the story that they miss the fundamental content being presented in the visual. Computer animations may serve to distract students from learning and therefore, should be used with discretion (Rieber, 1996).

Educational television increasingly uses 3-D computer animation in its programming. Schools also make such educational videos available to teachers and their students. However, teachers in today's schools are often standards driven and do not want to adopt materials unless those materials directly address specific skills identified and assessed by their states. They fear that "edutainment" will interfere with their student's skill attainment (Healy, 1998).

However, artfully designed videos created with computer graphics technologies can have basic skills instruction embedded in animated, entertaining stories. Animation, especially as used in multimedia, has attracted the attention of instructional program developers as new software and hardware have made it increasingly easy to produce (Alessi & Trollip, 2001). The combination of two modern technologies, computers and video, hold great promise for clarifying concepts for learners, particularly those that have visual components.

Animation is defined as the process of generating a series of frames containing an object or objects so that each frame appears as an alteration of the previous frame to show motion. Animation, which is a popular favorite effect among producers of computer-based instruction, is most commonly used for cosmetic purposes, with the intent of impressing more than teaching. Research findings are mixed, indicating that animation's effects on learning are subtle. For an animation to teach, the motion being illustrated should be meaningful to the learning objective, and students may need to be carefully cued to the to-be-learned information (Rieber, 1994).

The dynamic features of animation can cue students' attentions to meaningful elements of visuals. Specifically, animation can be an effective tool or aid to improve learners' performance on visual learning tasks. The variety of colors and motion in animated presentations can add realism and stimulate students' interests in concepts under study. As Apostol (1991) said, "visualization is even more effective when the images are in motion." Studies of college age students have shown that those students who viewed animations that supplemented their texts scored higher on tests than did students who studied static visuals or no visuals at all (Lilienfield & Broering, 1994; Spotts & Swyer, 1996).

Lee (1996) conducted experiments examining the effects of animation in the enhancement of the problem solving and retention of scientific concepts in computer based modules across learners possessing different cognitive styles. One hundred and twenty-one undergraduate and graduate students of Virginia Polytechnic Institute and State University were exposed to two experimental treatment programs: animation and static visuals representing the operation of a bicycle tire pump. Participants were randomly assigned to either an animation and narration treatment group or a static visual and narration treatment group. A problem-solving and recall test was conducted immediately after the completion of each treatment. Participants receiving the animation treatment performed significantly better than those receiving a static visual treatment on problem solving but not on recall. Field-dependent students in the animation group generated approximately 40% more correct solutions to the problem solving test than those in the static visual group. Lee concluded that animations can contribute to higher order thinking for college-age students.

The positive effects of animation may be attributed to their power to motivate learners. Kelley (1994) evaluated a video consisting of computer-animated reconstruction of an architectural exhibition. The reconstruction was used as a supplement to architectural exhibits. As such, it was available to anyone who walked through the exhibit. The director of the office of university art collections reported that "the video brings the culture to life—especially for children—and it expands peoples' concept to the Mimbres culture." And, because it was short, most youngsters chose to watch it.

The effectiveness of animation on the instructional process depends on learner's characteristics (Heinich, Molenda, Russel, & Smaldino, 1999). According to Mayer and Gallini (1990), animation is more appropriate and desirable when used with novices or inexperienced learners than experts or experienced ones. One possible reason for this differentiation is that learners who have considerable previous experience can easily visualize events, objects, or concepts from the verbal description provided in text. They are more likely to come to the lesson with existing mental images or the ability to rapidly build them. Animated graphics help most when learners lack previous experience and knowledge concerning to-be-learned objects, phenomena, or concepts. They help inexperienced learner's bridge the gap between concrete experiences and symbolic representations of phenomena and events, and assist inexperienced learners in building effective, useful, mental images (Rieber, Boyce, & Assad, 1990).

There is some evidence to suggest that the effectiveness of animation on learning depends on the user's age (Rieber, Boyce, & Assad, 1990). Adults arrive at a learning situation already able to build mental imagery, while children are less sophisticated at this process. Therefore, animation may be even more effective for children than for adult learners, because adults rely less on external images than children. Providing adults with animated presentations may be unnecessary because verbal presentations with highly imaginable explanations can prompt internal images and sufficiently instruct adults without visual support. However, for children, animation can provide the visual information necessary for understanding and storing concepts in memory.

## Animation for Art Education

This research focuses on using artfully developed computer graphics to teach color theory to children between the ages of six and seven years. Education about color is important: it enhances visual perception, awakens creativity, and can facilitate students' creation of rich mental imagery; it leads to the real experience of color perception.

In elementary art education, color is best taught by visual example and then through student experimentation (Herberholz & Herberholz, 1994). Such traditional methods for learning color theory are time-consuming and labor-intensive. Prior to conducting this research, interviews conducted with art teachers from two elementary schools indicated that they traditionally teach basic color theory by showing students the standard color wheel and color chart books. Then, students conduct time-consuming exercises that involve mixing pigments and painting geometric designs. It is difficult to see the effects of various specular colors in an exercise until it is completely painted. Since such painting exercises may be tedious, students are unlikely to experiment with any part of the exercise once they have finished it. In fact, a typical course covers only a few exercises because each is repeated several times (Meier, 1985).

According to well-known art educators Donald Herberholz & Barbara Herberholz (1994), there are three sequential stages of artistic growth in a child's life. First, from two to four years of age children learn purely through "manipulation and discovery." They have little control over their lines, and colors are not used realistically. Second, from four to eight years of age they move into "the symbol stage." At the beginning of the symbol stage, color is not yet related to objects. Later in the symbol stage, the first color relationships are established, usually blue for sky, yellow for sun, and green and brown for grass or ground. By the end of the symbol stage, visual realism begins to dominate, and children begin to draw more of what they see rather than what they know. The geometric lines that they have been using to make their symbols gradually give way to more realistic lines and colors that depict their concept of the actual object they are drawing. This is the critical point at which students begin to be more aware of how things look in the real world and to sense a discrepancy between what they see and the symbols they have been using to represent them. In the third stage, children from nine to 12 years of age typically strive toward "realism." They want to be able to draw figures that are realistic. Correct colors are seen on objects and people. More perceptive children will attempt to shade objects, draw shadows, show motion, and make distant objects smaller with less detail. As Shiau (1989) stated, age differences significantly influence the perception of color.

## Objectives

The purpose of this research was to validate a process of teaching color theory to children ages six through seven years. This research determined whether the use of artfully designed, 3-D computer-generated images was an effective teaching device for helping children to understand color theory and for enhancing traditional methods. Visuals with aesthetic appeal embedded in a visual story were used to alleviate some of the problems in learning color theory the traditional way. Artfully designed, 3-D video animations may provide young learners with the visual information necessary to form mental images of the effects of color mixing. The following questions were addressed in this study:

1. Do artfully designed 3-D computer-generated video stories enhance learning or are such entertaining works a distraction from learning?
2. Do children attend to the content of artfully designed presentations or are they merely entertained?

Generalizations and conclusions in this study may be limited to first grade students in settings similar to those in which the study was conducted. In addition, findings may not extend beyond teaching of the specific content that was investigated in this study—color mixing. The design of this study did not include a control group. However, absence of a control group was not a serious threat to the internal validity because of the low likelihood that factors other than viewing the video would account for the change in students' performances.

## METHODOLOGY

We used a one-group pretest-posttest design (Gall, Borg, & Gall, 1996) to determine whether or not the artfully designed, 3-D computer-generated video stories enhanced learning of specific objectives. This design was appropriate because the school district did not permit differential services for its students. The design involved three steps. First, one of the researchers administered the pretest to measure both the ability to recognize the primary colors and the ability to mix colors to create complementary colors. Second, students received treatment in the form of the computer-animated video. And third, the researcher administered the posttest to measure the abilities to recognize the primary colors and to mix colors to create complementary colors. One of the researchers and the teacher observed students during the video and tested them after they watched the video to determine whether or not the students attended to the instructional content of the video.

The participants were 110 first grade male ($n$ = 63) and female ($n$=47) children from two elementary schools. The participants were selected randomly from first graders in two schools. Of the 180 tests collected, 110 parents signed and returned the consent form. The study was conducted as part of the student's regular art class. The first grade children were selected as the subject group because, according to art teachers from the two primary schools selected, children have their primary color mixing lesson during December and January of their first grade year. These students were in stage 2 of artistic growth, the time when children begin to relate specific colors realistically to objects (Herberholz & Herberholz, 1994). This investigation was conducted from the end of April until the middle of May after children had studied basic color mixing using traditional methods. Participation in the study was voluntary, and participants were allowed to withdraw at any time.

### Artfully Designed Three-Dimensional Computer Animation

The four-minute, animated story was created with *Softimage*, a high-level, 3-D modeling and animation software package. The story beautifully illustrated how the three primary colors (red, blue, and yellow) mix together and produce the secondary colors (purple, green, and orange) in the context of a story without words or narration but with dramatic background music. The visual story follows:

The viewers saw inside an art gallery during the night. Suddenly, light came into the gallery through a skylight in the ceiling and hit a painting by Mondrian, which had a red, blue, and yellow color composition. The picture came alive as three figures of each color. They walked around the gallery, searching until they found the picture that they most liked. It was Van Gogh's *Starry Night*. They all jumped into the picture and flew into the sky where they morphed into stars.

The red star and yellow star then swirled together to create a separate orange star. The blue star and the yellow star mixed to create a green star. The blue star and the red star mixed to create a purple star. Then, all six colors of stars (red, blue, yellow, orange, green, and purple), flew over a village and, at the end of the animated story, they created a rainbow.

## Procedures

The presentation was shown twice to the 110 first graders. The first time, the children watched without any discussions. When they watched the second time, they discussed the color names with each other. During the presentation, the investigator narrated the color names.

A test was administered twice: once before the children watched the computer animation and once after the computer animation. When the children arrived in class prior to watching the video, the test was administered and six color markers were provided for children. Because, at this stage, the reading and writing skills of the target audiences were not well developed, the questions on the test were read to the students, and the students answered them by coloring in a diagram. After the first test administration, the children watched the computer-animated video story. Then the same test was administered a second time. Again, six color markers (red, yellow, blue, green, orange, purple) were provided for children to color in a diagram.

Test items follow:

1. Given a choice of six colors, identify the color red by using the right marker to color in a circle.
2. Given a choice of six colors, identify the color blue by using the right marker to color in a circle.
3. Given a choice of six colors, identify the color yellow by using the right marker to color in a circle.
4. Given a choice of six colors, identify the color produced by mixing red and blue by using the right marker to color in a circle.

5. Given a choice of six colors, identify the color produced by mixing red and yellow by using the right marker to color in a circle.
6. Given a choice of six colors, identify the color produced by mixing yellow and blue by using the right marker to color in a circle.

The nonparametric test, Wilcoxon signed rank, was used to compare pretest and posttest scores. Although the number of participants was more than 30 and we assumed that the data were normally distributed, the potential violation of normality with a pretest/posttest design indicated use of the nonparametric test. This test is a distribution free test for paired data.

One can compare two binomial proportions when paired samples of data are available from the populations of process of interest. The normal approximation to the binomial distribution is the most frequently used distribution for these inferential techniques on binomial proportions from independent samples. Because the pretest revealed that answers to questions 1, 2, and 3 were already well known to most of the children, only questions 4, 5, and 6 were considered using the proportion test. It was, therefore, assumed that the samples were independent.

To learn whether or not the children attended to and enjoyed watching the 3-D computer-animated presentation and viewing its instructional content, one of the researchers and the teacher observed the students while they viewed the video and recorded the students movements. After the students viewed the video, the researcher asked the children to raise their hands if they enjoyed the video and to raise their hands if they did not enjoy the video.

## RESULTS

Participants' answers to questions 1, 2, and 3 on the pretest indicated that most participants were able to identify and name the three primary colors prior to viewing the animation. All students chose the right answer to question 1. One student didn't get the right answer to question 2. Two students didn't get the right answer to question 3. Questions 4, 5, and 6 concerned color mixing, and 67% of the children answered question 4 correctly; 59% of the children answered question 5 correctly; and 56% of the children answered question 6 correctly.

These results on the pretest showed that questions 4, 5, and 6, which concern color mixing, were the hardest for children to answer correctly. Although the children had received traditional instruction in color mixing prior to watching the video, they still did not have an understanding of the result of color mixing. Given these results, one could assume that the teaching of color theory would serve to enhance the children's basic understanding of color. Boys and girls received similar scores on the pretest (Table 1).

**Table 1**
The Percentage of Boys and Girls Who Answered the Questions Correctly on Pretest

| Questions | Boys *n* (%) (*n* = 63) | Girls *n* (%) (*n* = 47) | Total *n* (%) (*n* = 110) |
|---|---|---|---|
| 1 | 63 (100%) | 47 (100%) | 110 (100%) |
| 2 | 62 (98%) | 47 (100%) | 109 (99%) |
| 3 | 62 (98%) | 46 (98%) | 108 (98%) |
| 4 | 42 (67%) | 32 (65%) | 74 (67%) |
| 5 | 41 (65%) | 24 (50%) | 65 (59%) |
| 6 | 42 (67%) | 20 (42%) | 62 (56%) |

The mean and median of participants' scores were 5.9 and 6 respectively, where 6 was a perfect score. By comparison with the score before the presentation (mean 4.8, median 5), there was significant improvement in the participants' abilities to recognize the color names and identify colors that would result from mixing primary colors. The standard deviation also decreased from 1.8 to 0.2. Boys' scores increased from a mean of 4.95 to 5.86, and girls' scores increased from a mean of 4.53 to 5.98. It was shown that there was even improvement regardless of gender. Scores improved on each question except question one, since all the children answered that question correctly on both the pretest and posttest.

When comparing the results of scores on questions before the students watched the video (67%, 59%, and 56% each) with scores after they watched the video (98%, 97%, and 98%), we see obvious improvement. Ninety-five percent of boys got the right answer for each of questions 4, 5, and 6; and 100%, of girls answered questions 4 and 6 correctly, while 98%, of the girls answered question 5 correctly (Table 2).

**Table 2**

The Percentage of Boys and Girls Who Answered the Questions Correctly on Posttest

| Questions | Boys *n* (%) (*n* = 63) | Girls *n* (%) (*n* = 47) | Total *n* (%) (*n* = 110) |
|---|---|---|---|
| 1 | 63 (100%) | 47 (100%) | 110 (100%) |
| 2 | 63 (98%) | 47 (100%) | 110 (100%) |
| 3 | 63 (98%) | 47 (100%) | 110 (100%) |
| 4 | 60 (95%) | 47 (100%) | 107 (98%) |
| 5 | 60 (95%) | 46 (98%) | 106 (97%) |
| 6 | 60 (95%) | 47 (100%) | 107 (98%) |

The Wilcoxon rank-sum test revealed that after viewing the video the students scores improved significantly when compared to their scores on the pretest (*p*-valu*e* = 0.00). Both the boys and girls outperformed the groups before the presentation (*p*-value = 0.00 each) (Table 3).

**Table 3**

Difference on the Scores Before and After the Video

| | | *z* |
|---|---|---|
| Pretest of Total vs. Posttest of Total | (*n* = 110) | -7.1275 * |
| Pretest of Boys vs. Postttest of Boys | (*n* = 63) | -4.7849 * |
| Pretest of Girls vs. Posttest of Girls | (*n* = 47) | -5.2419 * |

Note. * $p < .05$

The proportions of correct answers of question 4, 5, and 6 after the presentation were significantly greater than those before the presentation (*p*-value at each of the three questions). Both the boys and the girls showed significant proportional improvement after the presentation (*p*-value = 0.00 at each question). These statistical results were agreeable since it was shown that the proportion of correct answers of each question, 42% ~ 67% was increased to 95%~100% after the presentation (Table 4).

**Table 4**

Improvement of the Scores after the Presentation

| Questions | Gender | Before *n*(%) | After *n* (%) | *p*-value of hypotheses (before < *n* result) | Results |
|---|---|---|---|---|---|
| 4 | Boys | 67 % | 95 % | $5.7 \times 10^{-5}$ | Increased |
| | Girls | 67 % | 100 % | $1.9 \times 10^{-5}$ | Increased |
| | Total | 67 % | 98 % | $4.0 \times 10^{-5}$ | Increased |
| 5 | Boys | 65 % | 95 % | $2.9 \times 10^{-5}$ | Increased |
| | Girls | 50 % | 98 % | $1.4 \times 10^{-7}$ | Increased |
| | Total | 59 % | 97 % | $2.1 \times 10^{-11}$ | Increased |
| 6 | Boys | 67 % | 95 % | $2.9 \times 10^{-5}$ | Increased |
| | Girls | 42 % | 100 % | $5.9 \times 10^{-9}$ | Increased |
| | Total | 56 % | 98 % | $4.6 \times 10^{-13}$ | Increased |

Observation of the children while they watched the video revealed that approximately 98 children out of 110 did not move their eyes from the presentation while they were watching. When the investigator asked whether they enjoyed the video, 105 of the children raised their hands; when asked if they did not enjoy the video, three children raised their hands. Two students did not respond to the questions (Table 5).

**Table 5**

Students Enjoyment of the Video

| Children's Responses | Frequency (*n* = 110) |
|---|---|
| No Response | 2 |
| Enjoyed Watching Presentation | 105 |
| Did Not Enjoy Watching Presentation | 3 |
| Total | 110 |

In summary, boys and girls performed the same on both the pretest and posttest, and their understanding of the results of color mixing improved, regardless of gender, after viewing the video. The 3-D computer-generated animation was entertaining and held most of the children's attention.

## CONCLUSIONS

The purpose of this research was to examine and determine whether or not an artfully designed, 3D-computer animation facilitated children's understandings of color theory, enhanced traditional teaching methods, and captured the children’s attention. Such animations have been professionally developed to support learning, and advances in computer technology have made it possible for educators to design and develop their own multimedia instructional materials using visuals that include animation.

We have shown that students can learn specific skills from computer animation and that entertaining instructional materials can substitute for pure entertainment and enhance direct instruction. We conclude that, because students can gain skills described in state standards, and because embedding instruction in entertaining stories holds student’s attention and may provide a context for memory enhancement, artfully designed, 3-D computer animation is an effective teaching and learning tool above and beyond traditional instruction. Such teaching and learning materials should not be overlooked merely because of their entertainment value. What matters in instruction delivered through any medium is that it requires active engagement and that it covers appropriate curricular content for learners. Such engagement can be achieved through fanciful story telling presented through video. Given that “television’s effects may be more subtle, but also more powerful and pervasive than most people believe,” (Healy, 1990, p. 195) content remains the most important consideration.

In fact, in this case, embedding concepts in an entertaining story did not interfere with learning—the context of the story gained and maintained students’ attention so that meaningful learning took place. Our findings support previous research studies that indicate that animation is both appropriate and helpful for young learners, novices, or those who lack knowledge (Mayer & Gallini, 1990; Rieber, et al., 1990).

This study dealt with teaching and learning about mixing the three primary color pigments to create the three secondary colors. Future research could explore the impact of creative animated stories to illustrate tertiary color, color contrast, color mixes with black and white, and color theory of light. Additional research is needed to investigate 3-D-generated video’s effects on memory of color when measured after a time lapse.

An important extension of this study would be to investigate the impact of adding computer-based manipulatives through interactive video to the animation developed for this investigation. Students could use the manipulatives to practice color mixing before, during, and/or after watching the entertaining video. Such software would directly engage students in learning the concepts and would provide “mindtools” for constructivist learning (Jonassen, Peck, & Wilson, 1999).

Active participation, often referred to as interactivity, can be facilitated through computer animation. One of the leaders in developing this form of computer animation is Tom DeFanti at the University of Illinois, Chicago Campus. DeFanti is responsible for the development of a tool known as GRASS, a three-dimensional, real-time system. Instruments within the system have the ability to aid artists—as well as scientists—in depicting their view of the culture, be they those of organisms, individuals, or society (Auzenne, 1994). In the hands of children, such interactive tools contribute to construction of meaning.

In Narrative-based Immersive Constructionists Collaborative Environments (NICE) from Electronic Visualization Lab & Interactive Computing Environments Lab at the University of Illinois at Chicago (Roussos, Johnson, Leigh, Vasilaskis, Barners, & Moher, 1997) children collaboratively construct, cultivate, and tend a healthy virtual garden. The 3-D virtual reality environment provides rewarding learning experiences that are otherwise difficult to obtain. Ecological systems are usually complex models with many variables and behaviors that children have difficulty visualizing. In NICE, computers are effective at reducing the complex model of gardening into simpler qualitative relationships—for example, not watering is bad, a moderate amount of water is good, too much water is bad. Virtual reality adds the qualities of immersion, direct engagement, immediate visual feedback, and exploration to such models. In the virtual garden, the child has the ability to scale and position parts of an ecosystem, or to accelerate time to observe quickly and directly effects of their changes. While in a real garden, they can learn how to plant; in the virtual garden they can learn how to think about plants, take on different roles, change their own size, and interact and cooperate with children at distant locations.

We envision a future collaborative environment for facilitating children's understandings of art principles. Based upon the findings of this research, such an environment would incorporate artfully designed stories to illustrate concepts and would include manipulatives for student generation of art products.

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