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Are Realistic or Are Abstract Visual Representations More Effective Tools in Technology-Based Geosciences Education?

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ABSTRACT

In this study, the researchers developed two visual representations for use in the geosciences context. One of the study's goals was to demonstrate the educational value of distinguishing realistic from abstract visual representations in order to explore which type of representation most improves students' cognitive understanding and learning of science. Four 4th-grade students were observed and videotaped while interacting with the developed representations. The researchers used the results to develop recommendations regarding useful pedagogical imagery.

Keywords: Geosciences, Instructional Design, Multimedia Instructions, Pedagogical Imagery, Science Visual, Visual Learning.
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1. Introduction

In education, the use of pictorial media has long been considered an important instructional variable supported by a number of theoretical considerations. A respectable body of visual literacy research supports the importance of visuals in education in general and science education in particular (Nielson, Hagen, & Muller, 1997; Watkins, Miller, & Brubaker, 2004). Some researchers have asserted that visuals clarify and enhance student learning (Evans, Watson, & Willow, 1987; Naps et al., 2003). Others believe that visuals bolster reading comprehension, helping poor readers to improve their understanding of the written word (Watkins et al., 2004) and fostering higher levels of recall and inference (Large, Beheshti, Breuleux, & Renaud, 1994).

Studies in the fields of visual literacy and multimedia literacy have yielded a multitude of findings supporting the importance and effectiveness of integrating visual representations into learning contexts and materials, particularly in the area of science instruction. Students in science classes are usually faced with an overwhelming and ever-changing quantity of written data. In this context, visual tools or representations are becoming key teaching, learning, and assessment tools. One assumption that underlies numerous statements regarding the effectiveness of visuals in education is that learners exploit

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different information processing channels when encountering auditory and visual information (Lubin, 2004).

Little is known about visual learning in geoscience contexts. Although studies have generated some data on visuals, animation, and learning, much more is needed, from the user's perspective, to guide the use of sophisticated imagery in instruction. In addition, there is a need to develop powerful frameworks for scientific visualization in learning and teaching and to adapt scientists' tools in order to study how teachers and learners might use them productively in their learning and teaching activities. Researchers have asserted the need for specific supportive structures in scientific visualization software architecture that provide what learners—rather than scientists—need (Pea, 2002).

The present study was designed to demonstrate the educational value of distinguishing realistic from abstract visual representations in order to determine which type of representation most improves students' cognitive understanding and learning of geosciences content.

2. Review of literature

2.1 Geosciences and learning from visuals

New tools that allow users to create stunning visual images have given researchers the perspective needed to forge new research directions. Digital materials are currently being developed for widespread use and reuse in the geosciences (Pea, 2002; Sumner, Dawe, & Devaul, 2002).

Interactive materials, multimedia, animations, movies, and traditional photographs and diagrams can be used to enhance ideas or illustrate complicated concepts. Visual tools such as these represent some of the best ways to facilitate students' learning of concepts and to support students' ability to apply what they have learned (James, 2002). However, tools alone do not shape research or create educational change. Communities of learning must be formed and brought together to develop a collective vision of how to best use these powerful tools for the advancement of science and the improvement of education inside and outside the classroom. Technologies for the use of visualizations are advancing much more rapidly than our knowledge of the perceptual and cognitive processes that they engage.

Some studies have reported that students exhibit improved spatial abilities in geology after receiving targeted multimedia instruction in the geosciences. In addition, some researchers believe that scientific visualization, when integrated into inquiry-based learning activities, could enable students of diverse abilities to develop an understanding of complex scientific phenomena (Pea, 2002). However, there is little research regarding the pedagogical role of photographs in school science (Schnotz, Picard, & Hron, 1993), and there is little data supporting the conclusion that spatial ability can be improved through instruction, that learning of geological content will improve as a result, and that differences in performance between the genders can be eliminated.

2.2 Visuals and their realism degree

One important factor that controls the use of animation is degree of realism. Realism increases when similarities exist between the developed object and the referenced one with respect to shape, details, color, composition, or motion (Anglin, Towers, & Levie, 1996; Heinich, Molenda, & Russell, 1985). In the media research literature, "realism is defined as a matter of faithfully copying nature" (Anglin et al., p. 761) However, no media form can be totally realistic; the real object or event will always have aspects that cannot be captured pictorially, even in a three-dimensional, color motion picture. Various visual media can, however, be categorized from highly abstract to relatively realistic (Heinich et al., 1985). Ample research has debated whether greater realism or greater abstraction is better for visual representation in general and for animation in particular. Some research has asserted that subjects perform better with animations that are based on realistic rather than abstract images (Gonzalez, 1996). Other research has provided evidence that realism can interfere with the processes of communication and learning under certain circumstances (Cridge, 1977; Heinich et al., 1985). Still other studies (Dwyer 1968a, 1968b, as cited in Engleshby, 1982) have concluded that a visual representation's position on a realism continuum is not a reliable predictor of learning efficiency for students. In further studies, however, Dwyer (1971, 1976) found that a small amount of realistic detail affects students' achievement.

Braden (1996) contended that abstract visualizations tend to be problematic when related to mental imagery, visual mnemonics, mental spatial manipulation, mental rehearsal, or mental recall.

3. Methodology

3.1 Participants

The sample in this exploratory pilot study was comprised of 4 fourth-grade students (2 males and 2 females). Participants were selected according to the following criteria: They needed to be native English speakers and high-performing students with no special needs. There was no direct relationship between the researcher and the students. Science teachers with whom the researcher had good relationships helped contact the students and arrange the interviews.

3.2 Materials

This study used four visuals representing geo-scientific information. Each sample set was comprised of two elements; these two elements were designed to communicate the same idea(s). The first set of visuals presented the idea that rivers shape the land. The second set of visuals presented two ideas: the idea that water moves from high ground to low (explicit idea) and the idea that water erodes land over time (implicit idea).

Although the two visuals in each set were similar in the geographic information they presented, they differed in their degree of realism. For example, in the first set of visuals, while one image was a photograph, the other was an illustration drawn by the researcher. In the second set of visuals, one sample was a video of an actual landscape, and the other was an animated illustration created by the researcher.

3.3 Procedures

Before beginning the interview, the researcher briefly explained the interview process and the study's goals to the students and stated that the data collected would be kept confidential. Students were encouraged to express their opinions of the study aloud.

During the observation period, the students were given two separate tasks. In the first task, students were presented with the photograph/illustration visual set. In the second task, students were presented with the video/animation visual set. Students were encouraged to discuss their opinions as well as to elaborate on their understanding of the differences between the different formats. Students were also asked which type of representation they preferred, which type of representation they believed most improved their learning, and why.

4. Data analysis

One-on-one interview sessions of approximately 45 minutes each were held at the students' school in a private classroom equipped with a computer station. The four visual representations were downloaded to the computer's hard disk. The tasks were presented in a webpage format. Video images were presented using Quicktime player, and the illustrated animation was presented with Macromedia Flash player.

4.1 Task one

In this task, students observed two visuals: One corresponded to a real photograph, and the other corresponded to an illustration.

1. What did you notice, what did you understand from the picture?

Student 1: "River, some tiny trees, and a lot of trash over different places."

Student 2: "I see an 'S.' I see some trees like a forest, mountains, natural bridge."

Figure1 : Sample 1, Still photograph.

Student 3: "It looks like an 'S' river, but it is not too deep; I can see beach [the student means the deposition area] or sand."

Student 4: "Muddy river, banks, curves."

2. What is the main idea of this representation?

Student 1: "How dirty a river can be? This dirt came to the river by erosion."

Student 2: "What kind of ecosystem is here?"

Student 3: "Teach us about the water cycle [evaporation]."

Student 4: "This river has a lot of curves and banks that are sloping down because the river flooded several times."

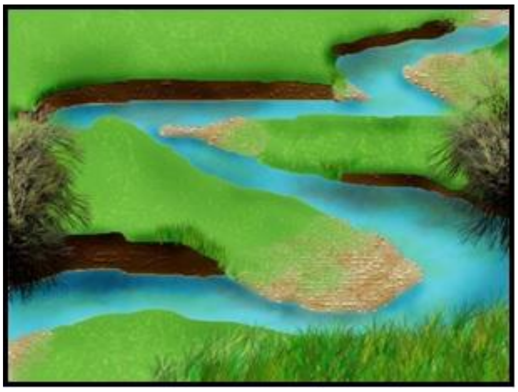

Figure 2: Sample 2, Illustration.

3. What is the main idea of this representation?

Student 1: "It is the same thing as the other one, but it is more modified. The grass is greener; the picture is like zooming in; it showed the areas of the dirt and where the erosion happened."

Student 2: "It is the same as the other one, except that it is made of cartoons."

Student 3: "It is the same but different; it is more like cartoons. I can see more beaches in this picture. There are no trees anymore like the first one, but only grass."

Student 4: "Same picture but is more animated, [it is a still drawing rather than an animation] to show what happen with the river before and now."

4. Which image explains the main idea better: the picture (Sample 1) or the drawing (Sample 2)? Why?

Student 1: "The drawing one. Because it shows the trees and the dirt places more clear, so it is more modified than the other one. The photo was dark and like that it was taken from a helicopter view."

Student 2: "The real one, because it shows that it is really real, while the cartoon looks fake and not tell that much."

Student 3: "The drawing one, because it looks prettier to me and more attractive because it is more cartoonish."

Student 4: "The real one, because you can see more details."

5. If you could change something in these representations, what would you change?

Student 1: "I would change the first one [photograph] and make it more clear, and make it look like the second one [illustration], which has little details [trees, trash], maybe add some text."

Student 2: "I would change how the water looks. I would like to see something in the water, like fish or rocks."

Student 3: "It depends on the idea of the learning. For example, if they want to teach us more about evaporation, it will be easier if they add some imaginary lines, precipitation [raindrops]."

Student 4: "Point out things that you want me to see this picture for."

4.2 Task two

In this task, students observed two thumbnails: One corresponded to a real video, and the other corresponded to an animated illustration. Students had the chance to choose with which thumbnail to start.

Student 1 chose the real video because "it is more real and when I will click on the drawing one I will know what changes and what is the difference between both of them."

Student 2 chose the animation because "the drawing one has more detail than the real one."

Student 3 chose the animation because "I like animation, movies, and cartoons. I would like to learn about how to create movies and cartoons. I know some things now because my father is very good in math and science."

Student 4 chose the real video because "the real picture in the first example showed more details, thus I wanted to see the details."

Figure 3: Real video thumbnail

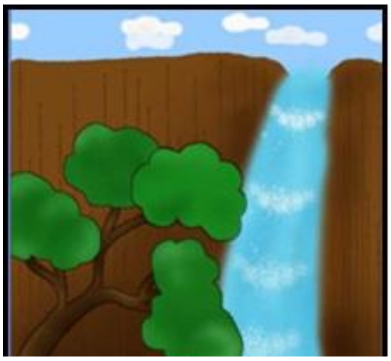
Figure 4: Animation thumbnail

6. What did you notice, what did you understand from this representation?

Student 1, real video: “There is a big tree and a waterfall.”

Student 2, animation: “This show how the water falls and how the tree grows.”

Student 3, animation: “Water is coming down. There are two arrows; I think it is pointing to the river or the edges of the cliff.”

Student 4, real video: “Waterfalls and arrows pointing to the top.”

7. What is the main idea of this representation?

Student 1, real video: “To show how water falls, and to show that there is a body of water over the top and then it’s falling down. The arrows help to show that water fallen from top to down. Also the video shows that the tree is going to serve on the water flow.”

Student 2, animation: “Evaporation, precipitation, and condensation.… The arrows show where the water comes from. Pretend that rains come from clouds and then to the waterfalls.”

Student 3, animation: “Precipitation, how waterfalls is going down, and maybe how waterfall helps trees and plants to grow.”

Student 4, real video: “How the water falls. The arrow’s pointed to the top of the hill to show how the water come and pushes the ground down and erode it.”

8. What is the main idea of this representation?

Student 1, animation: “This one is clearer than the other one. I thought that the arrows were pointing to the trees; now I can see that it is pointing to the places where the water is fallen.”

Student 2, real video: “This video has a lot of texture on it, looks more real. It shows us how water comes down.”

Student 3, real video: “The waterfalls looks more realistic. The arrows show the top of the waterfalls and the cliff. The tree is taller and more spread.”

Student 4, animation: “Show erosion again, except the hill in this animation doesn’t show erosion more clear.”

9. Which one explains the main idea better, the video or the animation? Why?

Student 1: The drawing one “because it is clearer. I like the arrows because they told me where to focus on.”

Student 2: The real one “because it shows the water moving, and the tree leaves are rustling. While in the cartoon one the water doesn’t change, the tree doesn’t move and there are some clouds, which make you think more. If someone saw the video, he may say, ‘Why we are watching this?’ But the arrows help to make us think more.”

Student 3: “This time I think it is the more real one because I think nature is a lot prettier when you see the real things. I would really prefer to learn science from the real thing because it is a lot easer to understand things when you look at them, but sometimes I think animations are very helpful because you can see some drawings and lines that clarify the idea.”

Student 4: The real one “because it gives you more details and tells you more about why it happened. The drawing one shoes you directly what is the idea. It is a waterfall and erosion. While the real one has a lot more details, which helps you to think, ‘but it could affect this or that.’”

10. If you could change something in these representations, what would you change?

Student 1: “Nothing; I like the second one because it is clearer.”

Student 2: “I would like to add some noise like water or birds’ voices. Also I would add some movement, like a bird flying.”

Do you think it is good if we add some text? “No, because people will just figure it out by reading the text. But without text, it makes me think more and guess what the teacher wants.”

Student 3: “To get the idea of the picture, you need to add some explanations—for example, teacher explains what to focus on, or read some paragraph of text.”

Student 4: “Red lines on the edges rather than arrows, because if a kid never heard about erosion and saw the arrows, he might not look at the edges, but will look to other things.

I would show this place millions years ago and how water changes these edges. I prefer in learning science to learn from both real things and drawing things. Real pictures give more detail, so it is better for a kid to see animation or drawing first, then at the end tell them this is what it looks like now [real picture].

I would add some titles like [erosion or changes] to the picture."

5. Discussion

Analysis of the data revealed several problems or difficulties that fourth-grade students faced while using the developed visualizations. In addition, data analysis led to several recommendations and directions for instructional designers and educators to follow in order to advance science and improve learning outcomes through the use of educational materials and visuals.

5.1 Students' problems

5.1.1 Vision scale ratio

In response to Sample 1 (the still photograph), Student 2 stated that she was able to see trees, rocks, and mountains. Sample 1, a zoomed photo showing a river with bushes and areas with deposition, did not include any trees or mountains. Rather, as a zoomed-in image, the picture showed grass and small stones, which the student mistook for trees and mountains.

Student 1 stated that he believed that this photo was taken from a helicopter, and that he would like it to be more zoomed. As the image is in fact highly zoomed, this comment shows that the student failed to understand the scale of the image accurately.

These two examples lend support to the idea that children are distracted by details and may miss the big picture. Some educators have found that children often become so engrossed in the details of a visual representation that they lose focus on the picture as a whole (Mackworth & Bruner, 1970). When these students were presented with more abstract images that did not include as many irrelevant details, they were able to figure out the scale ratio.

5.1.1 Different learning styles

This study shows that children have different learning preferences: Some prefer learning science through more realistic visualizations (Students 2 and 4), while others prefer more abstract visualizations. Students 3 and 4 also mentioned the importance of having both types of media. Given this diversity, the findings of this study support the use of varied visual representations (including differing degrees of realism) so as to ensure that all students have the best chance of learning desired concepts.

When addressing the video/animation sample set, Student 4 remarked briefly on the need for both types of visuals when learning science. This student, as well as other students, mentioned that more abstract visuals are usually clearer, more focused, and better at directing the viewer's attention. More abstract visuals also usually engage the imaginative part of children's minds. However, very abstract visuals do not connect the learned objective to the real world as well as do realistic images. This disconnect between real life and material learned in school can be frustrating for students. Abstract images can also be harder for students to understand, as students cannot relate prior experiences to the image and thereby decode its meaning.

The findings of this study align with other studies in showing evidence of individual differences and their significance in learning. Individual differences include differences in personality, cognition, verbal ability, spatial ability, and learning experience (Engleshby, 1982).

In short, while some methods of teaching are better than others, it is important to remember that all students learn differently and that various educational media have unique strengths and drawbacks. Instructional designers and teachers ought to present the same learning concept in different ways in order to maximize student learning.

5.1.3 Prior knowledge forces

It is well known that prior knowledge is one of the most powerful influences on learning and observation, so it was not surprising to find that some of the children's perceptions of the visuals were highly influenced by their prior classroom learning.

In the second task, the children observed a video and an animation, each of which depicted a waterfall. Two children (Students 2 and 3) thought that the main idea of these representations related to the water cycle. There was nothing in the two representations that suggested the idea of the water cycle.

However, the water cycle is an important topic in elementary school. Therefore, when these students saw water-related visuals, they assumed that the learning objective of the representation must have also been somehow related to evaporation, precipitation, and condensation. This finding aligns with the findings of Heinich et al. (1985), who stated that students must be guided toward decoding visual representations, as well as with the findings of Pozzer-Ardenghi and Roth (2004), who stated that when photographic imagery is introduced without a caption or related text, students' prior knowledge is evoked.

6. Recommendations for instructional designers and educators

6.1 Build children's visual literacy

In the first task, Student (4) viewed the photographic sample first and then the illustrated sample. She reacted by saying, "It is the same picture, but it is more animated." The two samples were still images and were not animated.

This comment suggests that, despite being gifted and appearing to have good visual skills, the student did not know the exact meaning of the term "animation" and therefore lacked visual literacy.

Given the increasingly widespread use of integrated visual representations in instructional material, learners must develop the visual literacy skills that will allow them to construct meaning from visuals. Student 4's misstatement is a case in point that learners must be schooled in visual literacy, just as they are trained in reading and writing (Heinich et al., 1985; Watkins et al., 2004).

In order to ensure that students get full use of visuals, instructional designers need to adapt visual content to the end user and teachers need to describe the nature and meaning of visual representations to students.

6.2 Employ useful pedagogical imagery

In this study, the prepared visuals did not fully explain the concepts of deposition and erosion. Instructional designers may be able to improve visuals by providing extra visual resources that help students interpret graphical representations, such as embedded text or a narration. However, instructional designers must not overload students' visual information-processing channel by adding a great deal of on-screen text; they should avoid splitting learners' attention between two sources (Mayer, Heiser, & Lonn, 2001).

Children concentrate more on details than do adults; they may be attracted by certain non-key aspects of representations for personal reasons and lose focus. However, details that do not distract from the main idea of a representation may be used to improve the attractiveness of the visualization itself. Examples include moving images and sound effects.

Visual designers need to be very clear about their message and very careful about how they communicate it. For instance, the use of arrows in a visual representation to focus the viewer's attention or show sequential movement is a very common technique. However, such visual elements may be inappropriate. In the second task of this study, there were red arrows in the video/animation samples pointing to the edges of the top of the waterfall. These were intended to direct the viewer's attention to water erosion and the way in which water can change the shape of the land. The students in this study did not interpret the arrows in this way; their interpretations included assuming that the arrows pointed to the cliff, to the top of the river, to the water source, or to something hidden. This shows that visual elements such as arrows may distract and confuse viewers. This study found that highlighting the waterfall's edges and circling particular areas were better ways of communicating than the use of arrows. Visual designers need to keep their target audience in mind when choosing visual elements. These findings are in keeping with literature reviews that stress that misused visuals can actually interfere with learning (Watkins et al., 2004)

This study aligns with others in supporting the recommendation that instructional designers and educators remain aware of the reception senses that they know that their learners will be using in order to filter information. It also supports the recommendation that instructional designers and educators attempt to reduce noise from visualizations to fit learning objectives and improve communication (Cridge, 1977).

This study also found that it was important to communicate the time factor visually in order to communicate the idea of erosion. For example, in the second task, Student 4 stated, "I would show this place millions [of] years ago and show how water changes these edges."

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