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ABSTRACT

This study explored computer-based image processing as a study strategy for middle school students' science concept learning. Specifically, the research examined the effects of computer graphics generation on science concept learning and the impact of using computer graphics to show interrelationships among concepts during study time. The 87 students who volunteered for this study were taking science classes at a rural public junior high school. They had previous skills with AppleWorks[TM] draw and paint software. Quantitative and qualitative methods were used to investigate the research topic. Findings showed that learner generated graphic representations of concepts provided a rich resource for the students' teachers. Representations of learners' understandings provided teachers with a way of knowing whether or not students were able to grasp concepts. Teachers suggested that if students cannot visualize the concept, perhaps they do not thoroughly understand the concept. It is essential to have all students engaged in the diverse practice of constructing their own concept representations while receiving feedback regarding their appropriateness. Educators are encouraged to prepare learners to use computers to visualize concepts during study time. An orientation to visualization skills can prepare students for using visual techniques to represent interrelationships among concepts. (AEF)

Concept Learning Through Image Processing

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Abstract

This study explored computer-based image processing as a study strategy for middle-schoolers' science concept learning. Specifically, researchers examined the effects of computer graphics generation on science concept learning and the impact of using computer graphics to show interrelationships among concepts during study time. Educators are encouraged to prepare learners to use computers to visualize concepts during study time. An orientation to visualization skills can prepare students for using visual techniques to represent interrelationships among concepts.

Background and Theoretical Perspective

Computer graphics software such as AppleWorks™ and PhotoShop™ have become pervasive in today's schools. Such software allow students to access a variety of tools that help them draw and paint objects to visually organize and represent what they know. Student-generated interpretative illustrations can help clarify the profound concepts expressed in texts and facilitate the comprehension of abstract concepts. When students are able to manipulate images during knowledge construction, they tend to engage more in the meaning-making process and understand and remember concepts better than through the traditional transmission approach of instruction (Jonassen, 2000). Additionally, students' graphic representations of what they know, can provide products for teacher feedback.

One approach for knowledge construction commonly used by students is concept mapping (Anderson-Inman & Ditson, 1999). Concept mapping refers to the "process for representing concepts and their relationships in graphical form, providing students with a visually rich way to organize and communicate what they know" (p.7). Research has suggested that students can study efficiently by generating concept maps (Anderson-Inman & Zeitz, 1993). Also, Cifuentes (1992) found that students who visualized interrelationships among concepts in their hand written study notes performed significantly higher on a test ($p= .02$) than those students who did not show such interrelationships. Concept mapping can be fostered through computer-based software such as Inspiration™. Additionally, images can be manipulated to show interrelationships with image-processing software such as AppleWork's™ drawing and painting tools. These visualization tools can be regarded as "mindtools" to extend and reorganize learners' cognitive structures during learning (Jonassen, 2000). Learners can use graphic conventions for organizing their thoughts as they construct knowledge of concepts (Dodge, 1998). Computer-generated graphics created by learners offer several advantages over pen and paper such as ease of subsequent revision and generation of sophisticated looking graphics by students with undeveloped artistic skill.

Objectives

This study explored computer-based image processing as a study strategy for middle school science concept learning. Specifically, researchers examined the effects of computer graphics generation on science concept learning and the impact of using computer graphics to show interrelationships among concepts during study time.

Methods

The 87 students engaged in this study were volunteers taking junior high school science classes at a rural, public, junior high school. They had previous skill with AppleWorks™ draw and paint software.

Quantitative and qualitative methods were used to investigate the research topic. Potential participants were the entire 7th and 8th grade student body of a rural school in Texas. However, some of those students did not turn in consent forms, some were absent for part of the treatment, and others were absent for testing. Therefore, 87 students participated in the complete study. Science classes were randomly divided in half from both the seventh and eighth grades so that approximately half of the student body were assigned to the control group (n= 46) and approximately half of the student body were assigned to the experimental group (n = 41). The groups were comparable across age, gender, and ethnicity. The control group consisted of 50% seventh graders and 50% eighth graders. 59% were male and 41% were female. 54% percent were Caucasian, 24% percent were African-American, and 22% percent were Hispanic. The experimental group consisted of 44% seventh graders and 56% eighth graders. 49% were male and 51% were female. 51% percent were Caucasian, 34% percent were African-American, 10% percent were Hispanic, and 5% identified themselves as a mixture of races. Participants were assigned to one of two groups, one receiving treatment and one for control, in a post-test-only-control-group design. Posttest scores were compared across groups. In addition, student's study strategies were compared qualitatively to help explain the impact of graphics on learning. The four data sources included: (a) immediate recall test, (b) students' study notes, (c) students' computer files, and (d) a Web-based "Study Strategies Questionnaire".

Quantitative aspect: All participating science courses were placed in a hat and drawn to randomly assign them to the two treatment groups:

- **Control group**-- received print-based, verbal material on a science concept (General Properties of Matter) and were given 50 minutes for unguided, independent study prior to the test. Students had access to computers during study time. At the end of the 50 minutes students kept both their study notes and reading material. The next day, and prior to taking the test, students handed in their study notes.
- **Experimental group**—participated in a workshop consisting of three 50-minute training sessions on how to manipulate and generate computer graphics during study time using materials developed by the researchers in AppleWorks™, Photoshop™, and PowerPoint™. They then received the same print-based, verbal material that the control group received. It was on a science concept (General Properties of Matter) and students were given 50 minutes to study prior to a test. At the end of the 50 minutes students kept both their study notes and reading material. The next day, and prior to taking the test, students handed in their study notes.

The three 50-minute workshop sessions on how to manipulate and generate computer graphics during study time had the following objectives: for students to be able to (a) recognize underlying structure of text (interrelationships), (b) illustrate underlying structure, (c) relate new concepts to prior knowledge, (d) highlight distinctive features, and (e) use graphics for review. The researchers facilitated the workshop. They modeled visualization of concepts using 7 underlying structures, gave the students a turn with each of the 7 underlying structures, modeled direct representation of concepts and highlighting distinctive features, gave the students a turn with direct representation and highlighting, and gave students 15 short texts to visualize. They encouraged students to keep their graphic representations and use them for study and review.

After taking the immediate recall test, participants filled in a Web-based "Study Strategies Questionnaire" that asked them to rate the extent that they had previously been exposed to the information in "General Properties of Matter?" To determine if groups varied in their prior knowledge of the textual material, a t-test was conducted. No difference was found. The questionnaire also asked students to describe in detail the steps that they took to prepare for the test. The testing instrument for immediate recall contained 30 multiple-choice items. All students took the immediate recall test at the end of their 50-minute study to determine the effects of the experimental treatment.

In addition, all participants' study notes and printouts of computer graphics were collected. Participants were asked on the Web-based survey to describe in detail the steps that they took to prepare for the test. The researchers rated the participants as visualizers or nonvisualizers based upon the students' study notes and study strategies reported on the survey. We classified students as visualizers if they used the computers to construct visuals while they studied for the test and/or reported that they hightlighted or drew while they studied. We classified students as nonvisualizers if they did not create visuals or highlight during study. The effects of treatment and application of visualization during study time on immediate recall were then estimated by comparing scores using planned contrasts in a general linear model.

The design avoided effects of initial bias, previous testing, maturation, instrumentation, regression, selection, and mortality because groups were randomly assigned and were not pretested.

Qualitative aspect:

We applied content analyses approaches, as described by Emerson, Fretz, and Shaw (1995), to the study notes, computer files, and survey results. During and upon completion of data collection, we used the two-phase process of content analyses, open coding and focused coding.

Results

The ANOVA revealed a negative treatment effect. The control group performed better than the experimental group and there was no statistical difference between the scores of visualizers and nonvisualizers. In addition, there was no interaction between group and strategy on students' performance.

In this case, computer-based image processing was not an effective study strategy for science concept learning. Middle school students were unable to identify or represent underlying structure. They claimed that visualization was too hard for them and they expressed lack of motivation. They were distracted by the computers and the fun software and were distracted by graphics tools. They spent their time creating irrelevant images and generated visuals that involved inefficient use of time.

The students who received the workshop in visualization as a study strategy did not perform better on the test on "The General Properties of Matter. Several environmental factors affected the impact of the workshop. Workshop time was insufficient and students had difficulty internalizing the visualization as a study strategy while they studied. Students were unable to manage their time for studying the entire text and meanwhile draw meaningful visuals to foster their understandings.

In addition, the students who visualized concepts while studying did not perform better on the test. They often spent time visualizing what they already knew rather than grappling with a new concept. The visuals generated by students were often inappropriate or misrepresented concepts and therefore could not facilitate concept learning (see Tables 1 and 2).

Table 1
Descriptive Statistics for Groups

Group	Strategy	Mean	Std. Deviation	N
Control	**Nonvisualizers**	14.11	5.48	36
	Visualizers	14.00	4.57	10
	Total	14.09	5.25	46
Experimental	**Nonvisualizers**	10.33	4.56	18
	Visualizers	13.30	3.30	23
	Total	12.00	4.13	41
Total	**Nonvisualizers**	12.85	5.45	54
	Visualizers	13.52	3.67	33
	Total	13.10	4.84	87

Table 2
ANOVA for Effects of Treatment and Visualization

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group	88.230	1	88.230	3.996	.049*
Strategy	36.061	1	36.061	1.633	.205
Group * Strategy	41.883	1	41.883	1.897	.172
Error	1832.425	83	22.077		
Total	16954.000	87			

R Squared = .091 (Adjusted R Squared = .058) * significance $p \leq .05$

We delivered the workshop in a naturalistic, rural school setting. Therefore, many unexpected environmental occurrences affected the delivery of the workshop. For instance, we encountered electrical failure in the projector, and were unable to model visualization processes on the presenter computer. We had to adopt "plan B" and use overhead transparencies. Of course, this meant that we were unable to model using graphics tools for visualization. All during the workshop, electricians and teachers came in and out of the computer lab to address the technological problems, or students would ask to go to get water or go to the restroom. Some students talked and visited with each other rather than focus on learning and some did not participate in parts of the workshop because of illness, extracurricular activities, or loss of interest. Additionally, the arrangements of the projector and students' workstations (chairs, tables, computers) were so inharmonic that students' positions had to shift to look at the presenter, projected images, and their computer screens alternately. Furthermore, because several computers in the lab were out of order, many students had to share computers with each other. Similarly, access to printers was limited. Only four out of the twenty computers were connected to the classroom printer, which made the preservation of students' work difficult. Students could not incorporate Web graphics into their visualizations because none of the computers were connected to the World Wide Web.

Moreover, the middle schoolers were extremely distracted by the software on the computers, especially the multimedia authoring software. Students tended to easily create sounds and irrelevant images on their computers. In addition, the 7th and 8th grade students spent a lot of time generating playful graphics or visuals that did not help them build their understandings. They did not make good use of their time for studying the entire assigned text. They tended to take the fun and easy route by visualizing what they already knew rather than grappling with a new concept. Several students said that they found identifying the underlying structure of the text to be quite difficult and we found that most students were often unable to create appropriate representations of new concepts. Most students were either unwilling or incapable of thoroughly and accurately representing texts. When, for instance, they were asked to represent the periods included in the Mesozoic Era, one student neglected to draw arrows in her timeline to indicate continuity and did not include the Mesozoic Era in her graphic. She also placed the periods in the wrong order on the timeline indicating her lack of understanding (see Figure 1). Another student misrepresented the visual of an iceberg. He was enthusiastic about drawing an iceberg, but ignored the text's main idea that only a small part of an iceberg is above the waterline and the rest of an iceberg is under water (see Figure 2).

Text to visualize: The Scientists divide the Mesozoic Era into three periods.
The oldest period is called the Triassic Period. The middle period is called the Jurassic Period. The youngest period is called the Cretaceous Period.

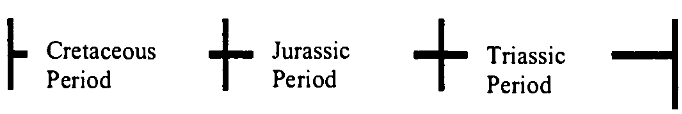


Figure 1. The misrepresentation of chronological information.

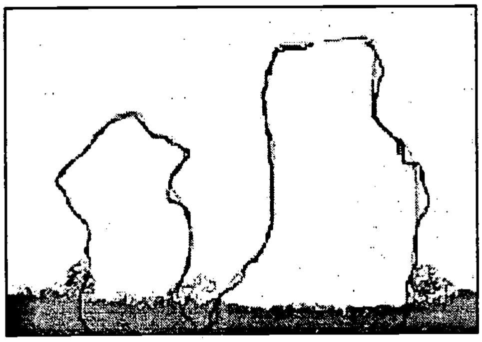


Figure 2. The misrepresented concept of icebergs.

On the other hand, some workshop participants successfully identified and visualized the underlying structure of the text they were studying. For instance, most students were able to successfully represent the sequence of the moon phases as well as chronology of periods within eras. Also, many students were able to directly represent concepts. For instance, one student generated a direct representation of how the earthworm breathes (see Figure 3).

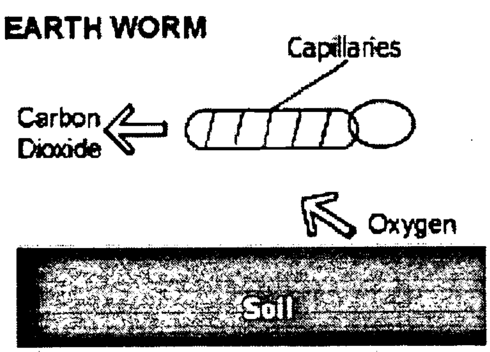
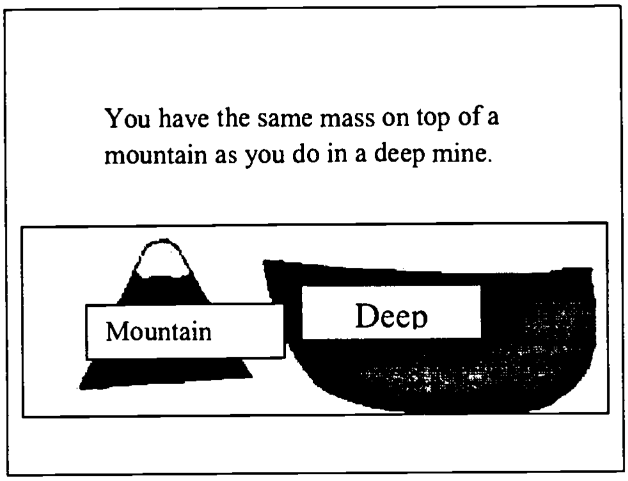


Figure 3. Student-generated visualization of the earthworm's respiratory process.

In general, the processes of identification of the underlying structure of concepts presented in texts and subsequent creation of visual representations associated with those concepts required a lot of time and effort from students. Such strategies facilitate memory because they involve the learner at a high level of cognitive processing by demanding extensive learner-effort. The visualization process helped most of our participants think hard about what they needed to learn, and learning that was not measured on the test resulted from such thinking. When students were able to extract meaning from text and generate representative images, they built their complete understandings. For example, as one student tried to understand that weight of an object changes according to altitude, but that mass remains the same, he generated a computer graphic accurately conveying an object with the same mass on a mountaintop and in a deep mine. Such kinds of visualizations concretized what students cognitively comprehended, and helped them clarify meaning of science concepts (see Figure 4).



<u>Figure 4.</u> Student-generated computer graphic

Educational Significance

We discovered that learner generated graphic representations of concepts provided a rich resource for the students' teachers. Representations of learner's understandings provided teachers with a way of knowing whether or not students grasp concepts. Teachers suggested that if students can not visualize the concept, perhaps they don't thoroughly understand the concept.

In summary, we delivered a visualization workshop designed to help learners use computer graphics to construct meaning while they study. When delivering visualization workshops in the natural setting of schools, problems are bound to arise. Technical failure, human interruptions, lack of active participation, limited access, distraction by alternate tools or games on computers, and differences in learners' abilities each affect the success of a workshop. Middle schoolers are unsophisticated learners and require guidance toward effective visualization. In our workshop, in spite of problems associated with the natural setting of a school, students engaged actively in the meaning-making process of studying while we provided scaffolding. Students who successfully formulated mental representations of concepts and then concretized those representations as computer graphics applied a strategy for spending time thinking in order to learn.

Still, they require cognitive apprenticeship and expert modeling of identifying the underlying structure of concepts. Given the 3-day workshop, students were unable to internalize the visualization methods as part of their study strategy. Most students were cognitively not ready to generate meaningful computer graphics while they study the textual information. They were more likely to highlight the important points by typing those words or sentences on computer than producing visuals concretizing those concepts. Middle schoolers might need extensive practice in constructing their own concept representations while receiving expert feedback regarding their appropriateness

The 7th and 8th grade students who participated in our workshop were not sophisticated visualizers. They needed expert modeling of identifying underlying structure of texts. It is essential to have all students engaged in the diverse practice of constructing their own concept representations while receiving expert feedback regarding their appropriateness. Additionally, the instructor should teach students in the sequence of increasingly complex tasks. When the learning task becomes more and more difficult for students to handle independently, the aids of peers and the close scaffolding of the instructor are of great importance.

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