The Role of Print and Video in Changing Science Misconceptions

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Abstract

One hundred fifty three fifth grade students found to have misconceptions about seasonal change were randomly assigned to either a video-print or print-video group. In Study One, each group read or viewed content about seasonal change and a free recall, multiple choice and application task were administered within the week following the treatment. Two weeks later, Study Two replicated the procedures with the groups receiving content in the alternate media. There were no significant differences found between media after each study. Exposure to both media favored the video-print order. Low and high ability readers performed significantly better on the free recall task after the print treatment with no significant difference between media among average ability readers. These results support previous research documenting the resistant of misconceptions to change. Differences inherent in the two media, differences specific to the text passage and video used in this study and variation in processing of the two media are possible explanations for the overall lack of significance found in the results. Implications for instruction include acknowledgement of the intricacies of constructing science concepts, the design of assessment measures, and the timing of assessing learning.

Purpose

Over the past thirty years more than 2800 studies have been produced in the field of conceptual change relating to science topics (Duit, 1993). The research in misconceptions does not merely document children's errors in science but views the student as actively transforming knowledge in ways that is consistent with their prior knowledge but scientifically inaccurate. The views children adopt, although erroneous, are seen as pervasive, resilient and psychologically compelling (Confrey, 1987).

The research in conceptual change follows theories that describe the conditions necessary for erroneous concepts to be corrected. Posner, Strike, Hewson and Gertzog's (1982) theory of conceptual change is cited as predominant in the research but multidimensional theories move beyond changes in knowledge structure and include the ontological, social/affective, and epistemological aspects of conceptual change (Venville & Treagust, 1998). Clearly, the learning of science is complex and may be informed not only by understanding cognition but the context in which the learning may be assisted. While the materials used in the classroom do not determine the learning of science, an examination of different media and their effect on conceptual change may offer helpful insights into their potential for instruction.

The role of images in communicating, beyond language, poses compelling questions about both sources of information. Kress (2000) suggests the multimodality that characterizes current communication is critical to acknowledge and explore since the effects of print and image on one another renders the study of either alone as incomplete.

Textbooks may not be the sole source of instruction in a science classroom yet they are still a prominent feature relied upon by many science teachers. Video, on the other hand, does not hold prominence in most classrooms. Of the two media, video is a significant part of a child's life outside the classroom and yet there is little known about its form, the mental operations it develops, the cognitive skills it affects and the ways in which the medium might be exploited to a learner's advantage (Flood & Lapp, 1995; Greenfield, 1984; Olson, 1974; Olson & Bruner, 1974). Considering the prominent role of images in conveying meaning, along with the less than sufficient progress many students make in science learning, the purpose of this study was to gain an understanding of the role that text and video might play, either alone or in concert, in bringing about conceptual change in the study of science.

Background

Studies examining the role of text in changing misconceptions in science approached research from the common premise of schema theory. Schema theory has pointed to one's prior knowledge as playing a key role in the meaning a reader makes of text (Bartlett, 1932). Although different labels referring to schema have been employed including "scripts" (Schank & Abelson, 1977), and "frames" (Minsky, 1975), schema theorists assign schemata, one's organized knowledge of the world, the role of providing much of the information from which

the reader comprehends, learning and remembers text (Anderson, 1994).

The activation of learners' prior knowledge before reading, ignoring learners' prior knowledge, and text structure have all been examined to more fully understand the role of print in learning new content. This research has revealed that students consistently retain their incorrect prior knowledge while ignoring correct print information (Alvermann, Smith, & Readence, 1985; Lipson, 1983; Anderson & Smith, 1984; Maria, 1987; Maria & MacGinitie, 1981). Studies examining the effect of activating or ignoring prior knowledge prior to reading text suggest that misconceptions tend to override new text information that is inconsistent with the reader's prior knowledge.

Lipson (1982) examined differences between low and average ability readers' use of prior knowledge when reading informational text. Readers who had no prior knowledge of the content before reading, particularly poor readers, performed better than those who had partial information about the content prior to reading. In a follow-up study, Lipson (1983) found that 4th, 5th and 6th grade students responded similarly to text when it was either totally unfamiliar or very familiar. It was when the information in the text was only partially familiar that students appeared to distort the text information so it was more closely aligned with their misconception.

Peeck, van den Bosch, and Kreupeling (1982) found in their study of fifth graders that readers whose prior knowledge was activated prior to reading retained significantly more information that was incongruous with their prior knowledge than those students whose prior knowledge was not. Alvermann, Smith and Readence's (1985) study of sixth graders revealed those whose misconceptions were activated prior to reading ignored incoming information from the text.

Studies of text structure examined expository text versus narrative text along with looking at the effect of refutation within text. Refutational text does not merely present new information but raises common misconceptions first and then directly refutes them before presenting the accurate version of the content. Studies revealed that refutational text was more effective in dispelling prior misconceptions than non-refutational text (Hynd & Alvermann, 1986; Maria & MacGinities, 1987). Maria and Johnson (1989) compared the effects of refutational narrative text with refutational and non-refutational expository text on fifth and seventh graders' misconceptions about seasonal change. Their results demonstrated that students consistently

performed better after reading narrative text than either of the other types of expository text. Alvermann and Hague (1989) and Alvermann and Hynd (1989) examined text structure and activation of prior knowledge prior to reading. Their findings suggest that merely activating prior knowledge is not as effective as activating existing misconceptions and then explicitly directing students to attend to ideas that may be in conflict with their own.

Though television research began in the early 1950s (Dorr, 1986), it was not until the late 1950s that researchers turned their focus toward examining television as a medium of information. A prevalent theory of television viewing, that viewer attention is primarily reactive and controlled by the television (Anderson & Lorch, 1983; Collins, 1983; Singer, 1980), characterizes the viewer as a passive recipient of salient information where the viewer's intentions, plans, strategies, and experiences are minimized (Anderson & Lorch, 1983; Collins, 1983). Anderson and Lorch, however, proposed a theory of television viewing which characterized it as "an active cognitive transaction between the young viewer, the television, and the viewing environment: (Anderson & Lorch, 1983, p. 6). Anderson and Lorch cite schema theorists as foundational to the premise of their theory that the cognitive processing of television is schema driven.

Anderson & Lorch (1983) suggest the fundamental difference between reactive and active television theories have to do with attention and comprehension. In reactive television theory, the primary causal relationship is from attention to comprehension and attention to television reduces comprehension. Jerome Singer (1980) proposes that attention to television occurs because of the movement and pattern on the screen that produces a continuous series of orienting reflexes in the viewer. Singer suggests that television's rapid pacing maintains the viewer's attention and may not allow the opportunity for reflection and mental reorganization of the content. Anderson & Lorch (1983) point out that Singer seems to suggest that the greater the attention to television, the poorer the comprehension. Television is seen as providing such an exceptionally powerful influence that the child becomes reactive in its presence, overtaking the child's ability to make judgments about attention and comprehension.

The active theory suggests that visual attention comes from ongoing comprehension processes i.e. the primary causal relationship is from comprehension to attention. A study by Lorch, Anderson and Levin (1979), from which Anderson & Lorch's (1983) model of children's television viewing was derived, revealed that children are semantically

processing both auditory and visual cues from a television program. When children look away from TV, they monitor the auditory information only to the extent necessary to detect auditory cues signaling a need to return their visual attention to the screen. Music, sound effects, change of voice, etc. that precede important content (Anderson & Levin, 1976) are the auditory cues that guide the child's visual attention back to the screen.

Pezdek and Hartman (1983) examined children's attention and comprehension of visual and auditory information on television. Their study demonstrated that, by age 5, children have developed cognitive processes enabling them to quickly determine which modality (auditory or visual) the information from the television program required and to adjust their patterns of attention while engaged in other activities (i.e. playing with toys, listening to a record).

The active theory of television viewing specifically addresses visual attention as a function of the viewer's need to make sense of program content. Acknowledging the role of prior knowledge and the viewing environment, the theory moves beyond the issue of visual attention as perception and into comprehension. This position draws upon schema theory and asserts the intentionality of visual attention in comprehending a television message.

Huston & Wright (1983) investigated children's processing of television content by examining the informative value of television's formal features. Their data supported their hypothesis that attention to television was elicited and maintained by the perceptual salience of its formal features. Furthermore, the researchers suggest that the salient features, by eliciting attention, influence that which is comprehended. From their study, Huston & Wright propose a sampling model of attention which advocates that the viewer samples the television program and makes a decision about continuing to attend to it based on the comprehensibility or predicted comprehensibility of the bit sampled.

Another facet of television comprehension is the generating of inferences (Beentjes & van der Voort, 1993; Collins, 1983; Collins, Wellman, Keniston & Westby, 1978; Gibbons, Anderson, Smith, Field & Fischer, 1986; Meringoff, 1980). The study of inferencing in television viewing began during the late 1970s when research turned toward examining television viewing as a process of comprehending information. Huston et al's (1981) studies of television's formal features suggest that television's form makes it likely that more

information is communicated than what is explicitly contained in the program.

Collins (1983) and Collins et al's (1978) studies examining the interplay between program structure and influence of prior knowledge indicate that children's understanding of television content is embedded in cognitive development and their prior knowledge.

Television's formal features (Huston-Stein & Wright, 1979; Huston, Wright, Wartella, Rice, Watkins, Campbell, & Potts, 1981), viewer comprehension (Bagggett, 1979; Beagles-Roo, & Gat, 1983; Calvert, Huston, Watkins, & Wright, 1982; Hayes & Kelly, 1985; Hayes, Kiely, & Mandel, 1986; Meringoff, Vibbert, Char, Fernie, Banker, & Bardner, 1983; Neuman, 1989; Pezdek & Hartmen, 1983; Pezdek, Lehrer, & Simon, 1984; Pezdek, Simon, Stoeckert, & Kiely, 1987), attention (Pezdek & Hartman, 1983; Pezdek & Stevens, 1984), inferencing (Beentjes & van der Voort, 1993; Collins, 1983; Collins, Wellman, Keniston, & Westby, 1978; Gibbons, Anderson, Smith, Field, & Fisher, 1986; Meringoff, 1980) and theories of television viewing (Anderson & Lorch, 1983; Salomon, 1979, 1984; Salomon & Leigh, 1984) were studied to more fully understand the unique properties of this medium.

Much of the research looking to further understand the particular information attended to and retained from television were cross-media studies that compared television to audio-only versions of the same content. Beentjes & van der Voort (1991) examined the specific nature of children's written recall after exposure to a print or television version of a story. Their results supported earlier studies demonstrating that children's recall of the video version was more precise than recall of the print version. The researchers pointed to the classroom implications that if the instructional goal was to encourage learners' use of imagination or to link information to personal experience the print medium was more effective. If precise recollection of content was desired, content was best presented in an audiovisual format as opposed to text.

Kress's (1999 & 2000) work points to the fundamental need for attention to the complexity of communication as rendered not only through print but through images. Pertinent to this study, in particular, are his questions regarding the potentially redundant or complementary relationship between language and images. As Kress (2000) underscores the unique attributes of images, which are spatial and nonsequential, and writing and speech, which are temporal and sequential, he asserts that language is no longer the sole carrier of

meaning. In his analysis of 13-year-old students' drawings and text after a science lesson, Kress comments that it was only from looking at both the students' drawings and writings that a sense of their knowledge could be determined. He goes on to suggest that, because each medium is well-suited to convey certain information, the selection of a medium to convey meaning is one of design and transformation for the text maker.

Considering the variations between the information potentially conveyed through image and printed language, this study focused on video and text versions of science content in order to explore their potential for changing cognitive misconceptions.

Subjects

This study was conducted with 153 fifth grade students from six classrooms in three elementary schools in a suburban school district of a major metropolitan area. The school districts represented a range of socioeconomic levels though predominantly middle class. Subjects were categorized as low, average, or high ability readers based on teacher ranking of their reading performance in class. They were then randomly assigned to one of two dual treatment groups. Data from students who did not complete the series of tasks in each study were not included in the analyses. There were a total of 29 students who did not complete one or more of the tasks. The mortality was near 20%, resulting in N=124.

Material Selection

Previous research in changing cognitive misconceptions identified seasonal change as a topic about which there are commonly held misconceptions (Maria & Junge, 1993; Maria & Johnson, 1989). A print passage about seasonal change written for earlier research (Maria & Johnson, 1989; Maria, Qian, & McHugh, 1995) was identified for use in this study. The text was revised to remove all diagrams, text references to diagrams, and two refutational statements. The revised passage was 832 words, conformed to a text structure identified by Armbruster (1984) as enhancing comprehensibility of text, and had a fourth grade readability level as determined by Fry's (1977) readability formula.

There was one educational video addressing seasonal change identified, Why We Have Seasons (Stevenson & Matulavich, 1989), that was appropriate in length, content, and suggested target

audience. The video was non-refutational and included electronic graphics, demonstrations with models in a classroom setting, and analogic references.

Design

A 2 (type of media) x 3 (low, average, high reading ability) experimental design was employed. There were two dual treatment groups. Study One consisted of both groups receiving one treatment (either video or print) and then being tested using immediate and delayed measures. Study Two consisted of both groups receiving the alternate treatment and then being tested using the same immediate and delayed tests.

Procedures

A ten-item multiple-choice test (Marshall, 1987) was administered to all subjects prior to the initial treatment to determine whether they held a common misconception about seasonal change (i.e. that the earth is hotter in the summer because it is closer to the sun and colder in the winter because it is further from the sun). All test items included the misconception that the earth's distance from the sun is the reason for seasonal change as one of the distractor answers. Two sample test items are the following:

- 1. Seasonal changes are the result of the Earth moving around the sun and

a. the tilt of the Earth on its axis.
b. the distance of the Earth from the sun.
c. the changes in the sun's radiant energy.

4. 2. Our days are longer in the summer because

5. the sun is closer to Earth.
6. the Northern Hemisphere is tilted toward the sun.
7. the sunrays are not blocked by clouds.

Those students with a score of 70% or below on the pretest were considered to hold incorrect views about seasonal change and were included in the data analysis.

Two weeks after administration of the pretest, Study One began. The video-print group received the video treatment and print-video group received the print treatment. Subjects in each group were told they were about to view/read information about what makes the seasons

change. All subjects were instructed to pay close attention to the information because they would be asked to complete an exercise afterwards.

Both groups were given equal periods of time in their treatment. All subjects finished reading the text within the time frame needed to complete the viewing of the video.

Immediately following the treatment subjects in both groups were given a free recall task. The following day, students were given the multiple-choice test that was administered as their pretest. One week following the treatment, subjects were given an application task (adapted from Maria & Johnson, 1989).

Two weeks after the end of Study One, Study Two began. The video-print group now read the print passage and the print-video group now viewed the videotape. The same procedures followed in Study One were repeated in Study Two.

Scoring of the Data

The multiple-choice test was scored as pass or fail. A passing score required that eight of the ten questions be answered correctly.

A rubric was created to score the free recall and application tasks in Study One and Study Two. The rubric assessed responses for the presence and quality of a tilt statement resulting in a score of accurate, inaccurate, or none. While the tilt of the earth is not the sole explanation for seasonal change, a full and accurate explanation of seasonal change is sufficiently complex to be beyond the capabilities of most fifth grade students (Sadler, 1997; Schneps & Sadler, 1988). Furthermore, both the print and video materials utilized in this study contain explicit statements of tilt as the primary reason for seasonal change. It was for these reasons the rubric scored only information provided by the subjects referencing the tilt of the earth. Any additional information, whether accurate or inaccurate, was not considered in the scoring.

Below are sample responses from subjects in the study in each of the scoring categories on the rubric:

"No Tilt Statement"

1. It is summer all year round by the equator.

2. If you put your hand to a light and turn it will get cooler.
3. That in North America people are sledding in Alstral people are swimming.
4. The earth is lined up all year on sides of the sun so when the earth is on the left it is summer and on right side it is winter and on bottom it is spring and on top it is fall.

"Inaccurate Tilt Statement"

It is colder in the winter because the earth is tilted further away from the sun. It is warmer in the summer because the earth is tilted toward the sun. The earth spins around the earth also rotating. It takes the earth one-year to go around the earth. While its going around the temperature is changing witch makes the seasons change.

"Accurate Tilt Statement"

The reason why we have changes for the seasons is the way the earth is tilted. When the earth is tilted toward the sun it is summer in North America. When the earth is tilted away from the sun its winter in North America and summer in South America when the earth is tilted some part receive less light and heat while other parts receive more heat and longer days. An experiment they showed had red flags at the end of wax as the globe got warmer the wax melted. The parts that had more direct sun melted quicker. The poles still had the flags on because it was colder in those areas.

Results

An ANOVA was conducted on all measures to determine the efficacy of each media after initial exposure, dual exposure, and the differences between media among each reading ability group.

On all measures in Study One and Study Two, after initial exposure, there were no significant differences between print and video in student performance.

A repeated measures ANOVA was used to examine the effects of dual treatment. There were no significant differences in performance between the video and print groups in Study One and Study Two. There was significance, $F(1,122)=5.16$, $p<.05$, on the interaction between the video and print groups in both studies on the free recall measure. Subjects in the print treatment, whether exposed initially or

secondarily, performed significantly better than those in the video treatment.

When examining groups by reading ability, there was a significant difference among low ability readers, $F(1, 18)=10.08$, $p<.01$, in the free recall measure in Study One with the print group ($M=1.58$) outperforming the video group ($M=1.0$).

Data from the repeated measures ANOVA for low ability readers revealed a significant difference $F(1, 18)=5.53$, $p<.05$, on the free recall measure. After initial exposure to a treatment, there was a significant difference between groups of low ability readers with the print group (M=1.58) outperforming the video group (M=1.0).

With respect to average ability readers, there were no significant differences between the video and print groups in either Study One or Study Two. There was a significant interaction, $F(1, 59)=4.78$, $p<.05$, between groups and studies on the free recall measure.

Among high ability readers, there were no significant differences on any measure in Study One. In Study Two, there was significance $F(1. 41)=17.63$, $p<.001$, on the multiple choice test where the print group ($M=1.56$) outperformed the video group ($M=1.05$).

The repeated measures ANOVA revealed a significant difference, $F(1, 41)=4.79$, $p<.05$, on the repeated free recall measure. On the multiple choice test there was a significant difference $F(1, 41)=12.45$, $p<.001$, between groups with the video-print group having a mean score of 1.476 and the print-video group a mean score of 1.10.

Discussion

The resistance of alternative conceptions to change is well documented in the research and these results support that research. The significance found in this does not suggest either media alone is an effective change agent for misconceptions.

One of the difficulties in examining the efficacy of two different media is that, by their nature, they differ in form. It is the differences between their symbol systems that make examining them a worthwhile pursuit. The video and print passages in this study were similar in that they both were non-refutational, addressed the concepts of rotation, revolution, tilt of the earth, angle of sunlight, and underscored that tilt is the primary reason for seasonal change.

Beyond these similarities, the two media differed in method of explanation, presentation, vocabulary, and degree of redundancy.

The structure of the print passage was of the type that would be found in a typical science textbook. Subheadings, bold print, underlining, capitalization, asterisks, and a summary were all forms of signaling (Armbruster, 1984) used in the text to emphasize important ideas. There were no narrative component, analogies, or reference to content that was not specific to the nature of seasonal change. Many of the concepts were referenced more than once in the passage. Most notably, the concept of tilt of the earth being a cause of seasonal change was repeated 24 times. The text passage was consistent in its vocabulary throughout referring to tilt of the earth, rotation, revolution, and direct, and indirect or slanted sunlight. Other science vocabulary such as axis, solstice, and equinox was included in the passage.

In contrast, the opening scenes in the video presented an artistic visual and auditory montage of four distinct seasons. Birds chirping, water rushing, wind howling and accompanying visual images set a tone for the video that was quite distinct from the print passage and from the pursuant content in the video. There was less scientific vocabulary used in the video to describe seasonal change and less repetition of terms. The terms "angel" and "angled" were repeated throughout the video but in reference to both the earth and the sun. The earth was described as being tilted or angled. Sunlight was described as being angled as well. There was only one statement in the video referring to the tilt of the earth as the primary cause of seasonal change. A classroom was the setting in the video for the scientific information about seasonal change. The content was conveyed primarily through demonstrations and analogies.

While analogies are frequently employed to draw a bridge between prior knowledge and new content, it a may be that the particular analogies used in the video reinforced the misconception that distance, not the earth’s tilt, causes the winter to be colder and summer to be warmer. In the video, a piece of paper bent in front of a light was specified as being analogous to the curvature of the earth. The narrator’s hand, shown facing but angled away from the light, was used to further demonstrate the earth’s tilt and the subsequent change in the angle of sunlight striking the earth.

Undoubtedly, many of the subjects in this study know, from personal experience, that a hand near a stove gets hot and a hand kept away

from the stove is cool. This early concept of the causal link between proximity to a heat source and its effect on temperature may be the source of the distance misconception about seasonal change. Without refuting this logical link, it would not be unexpected that viewers might generalize this concept to seasonal change. This is what makes the concept of tilt and seasonal change counterintuitive.

Another distinction between the text and video versions of this content was in its style of presentation. The print passage offered content that was directly supportive of the concepts related to seasonal change. The video contained information that may have distracted the viewer from scientific content. There was no signaling in the video that some context was more important than other content so, for example, cattle grazing in the emerald green pastures was presented with no less emphasis than the graph of the earth's orbit around the sun.

Another possible explanation for the print treatment being somewhat more effective than the video treatment may be due to the nature of the variability between reading and viewing conditions. Both groups were given equal time in their treatments whether viewing or reading. Readers, however, had their own text and may, as readers often do, have reread portions of the text more than once. Effective readers will monitor their comprehension and will reread portions of a text to resolve any gaps in comprehension. If a gap in comprehension occurred and was detected by the viewers, they were unable to review the tape. The video was played through once and viewers were not given the opportunity to stop, pause, or rewind the videotape. Within the treatment, therefore, readers may have had more repeated exposure to content than viewers.

These results do not support Beentjes and VanderVoort's (1991) findings that children produce more precise and accurate recall after exposure to information in a video format. The significant interaction between group and order is a result that is consistent with Salomon's (1979, 1984) theory of the variable effort expended in watching and reading based on perceptions of the difficulty or ease of either process. In both groups, it was after reading the content, whether initially or secondarily, that subjects' performed better on immediate free recall. This supports Salomon's theory that readers process content at a deeper level because they consider reading to be a more difficult task and assign more mental energy to performing it. Viewing, on the other hand, is perceived as an easier task and viewers spend less mental energy viewing and, consequently, process video less deeply. Perhaps Salomon's assertions regarding children's stance toward video as a

less difficult medium to process is a more potent explanation for low ability readers' better performance after reading.

Significance in this study was primarily found in the free recall task. There was significance in the multiple choice and application tasks only among high ability readers. There may be several plausible explanations for these results. First, in each study the free recall was administered immediately following the treatment. The lack of significance on delayed posttests and the predominance of significance on the immediate posttest suggest that it may have been short-term memory which produced higher performance rather than a learning of the content since there was no evidence of retention of content from Study One to Study Two.

Another possible explanation for the significance on the free recall measure and lack of significance on the other measures may be the nature and scoring of the instruments. The nature of the free recall was more open-ended than the other measures in that the only prompt it offered was to write down what was remembered from the reading or viewing. The multiple choice test forced choices which left no room for a constructed response whereas in the free recall a mix of both preconceptions and new ideas resulting from learning new content could have been communicated. The application task gave the specific directive to write a scientific explanation of seasonal change and to draw and label a picture of the position of the earth during its seasons. It may be that when given enough room to explore one's thinking about a topic there is a greater likelihood that more information will be included, thus increasing the chance that pertinent concepts will be addressed.

The scoring of the free recall allowed for one of three levels of responses including none, inaccurate, and accurate. Unlike the multiple choice test where an answer was either right or wrong, the tilt rubric in this study acknowledged that an incorrect explanation of seasonal change had a value because it was closer to an accurate response than no information at all.

The tilt rubric was also used in scoring the application task. The lack of significance on this measure may be due to the inclusion of a drawing as evidence of content knowledge. The drawing was considered in the scoring on the tilt rubric but there was greater ambiguity in the drawing than in the written information provided by the subjects. Tilt of the earth could be conveyed through the drawing but an explicit statement of tilt as the primary reason for seasonal change could only

be conveyed through language. Many subjects drew the earth tilted, which may have, in their minds, been sufficient to imply causality between tilt and seasons. The requirement for the highest score of "accurate" was, however, an explicit causal statement of tilt. In other words, their drawings may have been meant to convey more information than they did. By being asked to write, not draw, a response on the free recall the use of language may have increased the likelihood of a higher score on the rubric.

Since the multiple-choice test was used as the pretest in this study, it screened only for the absence of a correct notion about seasonal change. The pretest did not probe the exact nature of each subject's misconceptions. It only demonstrated that they did not have an accurate view. The significance on the free recall then, where an inaccurate statement was given weight, may not have been due to the treatment but may have been a pre-existing misconception.

The efficacy of print and video among different reading ability levels may be explained in several ways. An explanation for low readers' better performance after reading in Study One may come from Salomon's theory (1979, 1984) that print is perceived as a tougher media and more effort is expended in processing print than video. In other words, the effort expended in reading is greater than that in watching a video and, even among low ability readers, results in improved performance. This notion is supported in the decline in performance of the print group after they watched the video. Their higher scores do not hold across both treatments.

Implications for Learning

Schema theory suggests one's world knowledge is uniquely constructed making it possible for misconceptions to co-exist with more accurate views. The ways in which teachers assess student knowledge prior to and after exposure to content is important. Had this study examined only the results of the multiple-choice test, only the high ability readers would have demonstrated any increased knowledge. The ways in which educators attempt to measure progress in students' knowledge must be sensitive enough to allow changes in preconceptions to surface.

When using measures that are more open-ended than multiple choice test caution is still in order. As cited in Bransford (1994), Barclay, Bransford, Franks, McCarrell, & Nitsch discovered that even very subtle mismatches between a learner's initial conceptions and the

teacher's phrasing of test questions can cause significant misinterpretation of student knowledge. In this study, when a student described summer as occurring when the United States is facing the sun may or may not be describing tilt. Facing could accurately refer to being tilted toward or away from the sun or, it could refer to, as was discovered in one subject's drawing, rotation. The subject's picture showed the earth upright and the United States facing the sun in summer and rotated 180 degrees and in darkness in the winter. Without the accompanying illustration, a teacher might have assumed the student to be describing the earth's tilt. Bransford points out that extended one-on-one conversation between teacher and student to more fully assess a student's understanding is not practical in the classroom. The tools used to assess the learners' understanding of content must be open enough to allow for full expression of the learner's thinking about content.

Acknowledging that learning may not occur in a sequential pattern is a step toward recognizing the intricacies of learning and the measurement of that learning. Preliminary evidence that misconceptions may actually get stronger before they are changed (Sadler, 1997) is of profound significance to those who teach and those who judge teachers by their students' performance. It is not only *how* a learner's knowledge is measured that must be evaluated but also *when* the measurement occurs. The traditional teach-then-test model of instruction may offer false impressions of both success and failure.

Implications for Teaching

The results from this study suggest possible, though not definitive, approaches to teaching science content that incorporate media in a manner consistent with these results. While video may be perceived as entertainment rather than educational, the use of video in the classroom is worthy of pursuit since much of what children encounter outside the classroom is in the form of images, as well as print. Lest educators seek only to foster learning within the classroom, students' experiences with video as a serious educational medium may widen the power of video beyond its main use as entertainment. The possibilities for using video and text to teach science are numerous. The following three strategies suggest possible variations of using video and text which may foster an attention and processing of video that could widen students' access to information, particularly those students of low reading ability:

1. Conduct a demonstration in class, using a model of the sun and earth, representing the rotation, revolution, and tilt of the earth. Without an accompanying verbal explanation, ask students to write about what they see. In the absence of speech, children not only must rely solely on the visual image of the demonstration but also then translate that understanding into their own language. Attention to the images may be heightened and students' use of language to convey their understanding may lend support to Kress's (2000) contention that both language and image have exclusive and complementary roles in communicating meaning. This demonstration could be followed by discussion of children's written descriptions and the variations between their renderings. The intent of this experience would be to isolate image from language in order to heighten children's awareness of the amount of information contained in images and, therefore, increase their attention to the visual information in a video program.
2. After viewing, engage children in a constructed response to the information from the video. A whole class discussion would render a richer, perhaps more divergent, explanation of the content in the video and will afford a natural opportunity for children to hear their own and other's verbal rendition of the content in the video. This discussion could yield opportunities for confronting and refuting misconceptions.
3. Pair children of varying reading abilities together and ask that they co-author a written response, including drawings, to the video. The collaboration would benefit low ability readers by neutralizing the role of written language and valuing the pictorial information the students construct. The writing process engages children in actively reading as they work to draft, revise, and edit their written work. Children's negotiation during the collaboration of how to create a full response using both language and drawings may strengthen each student's awareness of the power of each symbol system and the interplay between image and text.

The intent of each of these classroom events is to help all children, particularly low ability readers, expand their communicative capabilities. Facilitating the active construction of meaning, regardless of the source of information, may help to not only expand the child's range of modes for communicating but expand the child's ability to receive and process more information, as well.

Future Research

To more fully understand the unique properties of print and video in the context of learning science content, qualitative study of the nature of what is learned after viewing and after reading is in order. What are the differences both between the two media and within each media in what is learned? Of specific importance is a look at whether visual information from a video is learned more readily than audio information and whether print can elicit a visual construct of a concept from the learner. Are there differences between viewing a video versus a live demonstration of content? What is the role of refutation in both print and video materials?

A replication of this study incorporating direct teaching of content accompanying each media form may produce more significance on measures of learning. In addition, post-viewing and post-reading interviews of students may reveal significant information regarding their attention, attitude, and metacognitive awareness of their learning from either or both media. This would be of particular value if students were asked to use pictures and print as means for conveying their understanding. Interviews probing the intent of the child's response may disambiguate the pictures and offer an even fuller explanation of the understanding the child was attempting to communicate.

In general, further study of the role of prior knowledge in learning is important to the understanding of how a learner's ideas about science influence the development of more accurate views. While the teaching of science does not rely solely on text or video, specific research examining the effects that these media play in constructed meanings will contribute to both the on-going advancement of the teaching of science and what we understand literacy to be.

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