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A study of student's abilities to detect scientific inaccuracies in selected illustrations

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selected illustrations**

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San Jose State University, 1992

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**A STUDY OF STUDENTS' ABILITIES TO DETECT SCIENTIFIC
INACCURACIES IN SELECTED ILLUSTRATIONS**

A Thesis

Presented to

The Faculty of the Division of Teacher Education

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Donald Blagsvedt

August, 1992

APPROVED FOR THE COLLEGE OF EDUCATION

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ABSTRACT

A Study of Students' Abilities to Detect Scientific Inaccuracies in Selected Illustrations by Don L. Blagsvedt

Third, fifth, and eighth grade students from the Monterey Peninsula Unified School District were tested to determine whether they could detect scientific inaccuracies in illustrations that are typically used for motivational purposes within instructional materials. Students' identifications and descriptions of errors in pictures were compared to responses on an objective assessment that measured the same knowledge. Analysis of responses indicates that (1) students may identify an illustration as incorrect but may not be able to identify the associated scientific error, (2) student ability to detect scientific inaccuracies in illustrations does not necessarily correspond to grade level, (3) alternate conceptions surface when students are asked to detect scientific inaccuracies in illustrations, and (4) knowledge reflected by responses to the set of illustrations is not the same as knowledge reflected by responses to the objective test.

Results support the notion that students bring varied understandings to the interpretation of science content presented in instructional materials. In particular, the results suggest that teachers should not assume that students can detect inaccuracies in pictures. Classroom practices that encourage (1) the interpretation of pictures, (2) the discussion of scientific inaccuracies in informal illustrations, and (3) the use of assessments that require reflective thinking serve as effective strategies for the teacher to learn about students' understandings of science concepts.

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CHAPTER I

INTRODUCTION

It is generally accepted that the understanding of science concepts is enhanced by illustrations and other visual aids commonly used in science classrooms. Visual aids such as graphs, charts, diagrams, photographs, drawings, and other illustrations are used to present information for instructional purposes. Illustrations that are used for motivational purposes, especially cartoons and pictures of animals with human features, are also common in instructional materials. Motivational illustrations are used to elicit a favorable response to a lesson or to garner more interest in completing a work-related task.

Because of the extensive use of motivational illustrations, especially at the elementary level, it is of interest to consider the impact these illustrations have upon students' learning. A survey of three text-based programs and other instructional materials, carried out prior to this study, confirmed that most illustrations and visual aids selected for instructional purposes accurately portray information that supports the main ideas and concepts in a lesson. In contrast, motivational illustrations often contain scientific inaccuracies which may go unnoticed by the student, the teacher, and the adult illustrator. Common examples of inaccuracies are fish that blow bubbles and clouds with happy faces. Illustrations in children's books often anthropomorphise animals and inanimate objects. Cartoons portray characters that defy laws of gravity. Animated movies show humans and dinosaurs living in the same time period. For a variety of reasons, students often are not asked for their understanding of these pictures: it is not the time to "do science," it distracts from the purpose of

the lesson or story, the inaccuracy is not noticed, or it is assumed that children will grasp the "humor" or deliberate intrusion of scientific inaccuracies.

Most of the literature related to the issue of how students interpret illustrations in science focuses on relationships between illustrations designed to support the text and retention of text information (Peeck, 1987). Relationships between illustrations in informal, or non-instructional contexts, and students' understandings of concepts depicted are lacking in the literature.

Investigation of the ways humans organize and process different kinds of knowledge contributes to an understanding of how students derive meaning from visual images. The notions of schemata (West, Farmer, & Wolfe, 1991), right and left hemisphere of the brain (Edward, 1989), and multiple intelligences (Gardner, 1983) can help explain the role of pictures in learning.

Research that examines student abilities to interpret information, such as detecting scientific inaccuracies in illustrations, can complement pertinent studies that have been conducted over the last fifteen years on children's ideas about science (Bell, 1981, 1985; Driver & Bell, 1986; Osborne & Freyberg, 1985; Tamir, Gal-Goppin & Nussinovitz, 1981; Trowbridge & Mintzes, 1988). These ideas have been investigated with a focus on the strong discrepancies between what the teacher assumes has been taught and what is actually learned by the student.

A student encounters hundreds of visual images each day. Many of these images contain scientific inaccuracies. Are students able to detect inaccuracies in illustrations? Do illustrations serve to reinforce or maintain misunderstandings that students bring into the classroom?

Problem Statement

Many motivational illustrations that students encounter both in and out of the classroom contain scientific inaccuracies. Little research has been done concerning how students interpret illustrations that contain inaccuracies. Teachers have little information about students' abilities to detect scientific inaccuracies in illustrations.

Purpose Statement

The purpose of this study was to (1) determine whether students can detect scientific inaccuracies in selected illustrations, (2) compare student responses to the set of illustrations to answers on an objective test that measures knowledge content similar to that depicted in the illustrations and, (3) determine whether patterns of responses exist in relation to grade level with both the illustration and objective assessment.

Research Questions

The following are research questions addressed in the study:

1. Can students detect scientific inaccuracies in illustrations?
2. Are there significant differences between responses given by third, fifth, and eighth grade students on the two kinds of assessment?
3. What are some key characteristics and patterns of understanding revealed by the responses of third, fifth, and eighth grade students asked to identify scientific inaccuracies in illustrations?

4. Are patterns of understanding revealed by student responses to illustrations different from those revealed by responses to an objective test that assesses the same content knowledge?

Hypotheses

The general hypotheses addressed in this study are listed below. See Chapter III for a complete set of hypotheses for each illustration.

- a. Fewer than 50% of students in third, fifth, and eighth grades demonstrate an ability to detect scientific inaccuracies in illustrations
- b. Students in higher grades are more able to detect scientific inaccuracies in illustrations than students in lower grades.
- c. Knowledge demonstrated by students inspecting pictures is different from knowledge demonstrated by responding to objective tests.

Operational Definitions

For the purposes of the study, key terms are defined as follows:

1. *Alternate conceptions*: Students' prior knowledge which may reflect ideas that are at variance with the generally accepted scientific view. Generally, these ideas are generated from the student's own attempts at formulating common sense explanations of the natural world (Head, 1986). In other studies, these ideas have been referred to as misconceptions, preconceptions, and alternative frameworks.
2. *Conceptual understanding*: Knowledge based on linking together the important ideas associated with a scientific phenomenon and being able to

apply this understanding (Smith, 1990).

3. *Objective Assessment*: The twelve item test used in this study that incorporates multiple choice, true-false, and complete-the-drawing formats.
4. *Perception*: The process of attaching meaning to an event within the schemata available (West, Farmer, & Wolfe, 1991, p. 9). Perception is an active, constructive, selective, and schema-driven process.
5. *Picture Superiority Effect (PSE)*: Pictures and illustrations that demonstrate a positive effect upon retention of text material (Reid, 1990).
6. *Schemata*: The knowledge structures that humans use to process and organize information (West et al).
- 7 *Sense impressions*: Understandings of the world that are based upon common sense explanations and intuition rather than reason or scientific explanations (Head, 1986).

Assumptions

During the course of the study, the following was assumed:

1. Students were able to read all questions posed on both assessments. If not, students would ask for clarification.
2. All teachers carried out the procedures prescribed for the study.
3. Instructions given to students were uniformly understood whether given orally or by videotape.

Limitations

1. The sample is limited to 330 students in third, fifth, and eighth grades in the Monterey Peninsula Unified School District, Monterey, California.
2. Follow-up interviews were not conducted to clarify student responses.
3. The illustrations consisted only of black line drawings.
4. Student disinterest in a research project might affect quality of response.
5. The time lag between the administration of the two assessments, detecting scientific errors in illustrations and the objective assessment of content knowledge, varied from 1 1/2 to 3 weeks, a factor that might affect the correlation of responses.

Statement of Significance

This study was designed to determine students' abilities to detect scientific inaccuracies in illustrations. This study contributes to the knowledge base about children's ideas in science and specifically, provides information about patterns of responses to motivational illustrations that are scientifically inaccurate.

Two kinds of assessment were used in this study: one involving open-ended inspection of illustrations and the other requiring objective responses to questions about specific science content. Reflection on these contrasting kinds of assessment can add to our understanding of the strengths and limitations of different assessment strategies. In addition, the study provides information about whether students in higher grades are more able to detect scientific inaccuracies than students in lower grades.

Findings from this study could relate to investigations of how students interpret other forms of visual images that contain scientific inaccuracies such as those in advertisements, television programs, and comic books.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this chapter is to (1) review studies related to how students interpret illustrations used in science contexts, (2) relate how researchers categorize different kinds of knowledge to the processing of visual images, and (3) provide an overview of children's ideas in science as they relate to the study. This review provides background and perspectives from which to recognize limitations and reflect upon the results of this study.

Illustration Studies

The commonly held assumption that illustrations enhance learning in science is supported by research, particularly from studies carried out in the middle 1970's on. For example, Holliday, Bruner and Donais (1977) investigated the effect of flow diagrams on student understanding of biological concepts. Thirty-seven biological concepts, such as the nitrogen, carbon, and water cycles, were covered in the teaching unit. The control group was given an instructional module that used block word diagrams. The other group was given an instructional module that used picture-word diagrams. Students were also divided into low and high verbal ability groups. The low verbal ability students who used the picture-word diagrams scored significantly higher than low verbal ability students who used the block word diagrams. High verbal ability students performed about the same with either learning approach. This

suggest that illustrations are particularly important in enhancing the performance of low verbal ability students.

Most of the illustration research relates to how illustrations affect memory retention and recall of textbook material (Blystone & Dettling, 1990; Newton, 1984; Peeck, 1987). In this regard, there is evidence that illustrations that accompany text information have a positive effect upon student understanding of that material, a phenomenon that has been labeled PSE, or picture superiority effect. It is commonly accepted that pictures arouse interest and curiosity, and extend the reader's willingness to pay attention. Yet there is no clear evidence that more attention paid to illustrations enhances conceptual understanding. Reid (1990) reviewed studies that examine the PSE factor and found that lower achieving children look at pictures more often than higher achievers. The lack of ability to assimilate written material may result in a tendency to flip back and forth between text and pictures. Reid's findings indicate that a positive PSE correlation occurs when the task involved is fact-based. When the task involves deciphering concepts or determining main ideas, PSE is not conclusive as a relevant factor. Although more research is needed in this area, PSE surprisingly appears to have a greater role in easy-to-read text than in more difficult-to-read text.

Peeck (1987) has examined the effect of mismatched pictures upon student understanding. Students were given items that had an inconsistency between text and illustration. If students were not alerted to the mismatch, students tended to choose the illustration-related material over the text material as correct even though the illustration contained the error. Follow-up studies showed that when text and illustration material were compared, retention of

information was based strongly on what was seen in the pictorial supplements.

In the early part of this century there were attempts to articulate cognitive stages of development as they relate to interpretations of pictures (Peeck). The French psychologists, Binet, in 1908, and Stern, in 1930, suggested that these developmental stages occur in the interpretation of pictures:

1. Before the age of seven, an individual will only enumerate objects in a picture.
2. About the age of seven, a child will mention relationships that occur in pictures, e.g., the man is chopping wood.
3. After the age of twelve, the child is able to identify themes implied by the picture, e.g., chopping wood has an environmental impact.

More recently, Peeck (1987) cites the work of Van Parreren who has studied how adults and children interpret pictures. Unlike children, adults do not treat illustrations as separate items but look at pictures in a systematic way and try to find common connections among different illustrations.

Some researchers approach the study of illustrations from a constructivist perspective. They assert that pictures do not just tell a story but that learners construct their own meaning of a picture based upon their perceptions from prior experiences (Levie, 1987; Reid, 1990). Reid states that the variables of sex, age, intelligence and culture, factors that he defines as a "pre-perceptual filter," all affect what the learner sees on a conscious and unconscious level. Factors such as color, shape delineation, and depth of field play a significant role in determining what observations and perceptions are made by the viewer (Reid, 1990). For instance, errors or discrepancies that may occur in an illustration are more easily detected in the foreground. When 13-14 year old

students (n=126) were asked to interpret two types of butterfly illustrations, colored and black and white, many more detailed observations pertaining to thin legs, number of wings, and veins in the wing were made when students observed the colored illustration. Although color in an illustration may increase the number of observations, there was no evidence to show that this variable affects quality of responses or number of scientific responses.

In acquiring new knowledge, the critical factor in perception becomes the experiential bias (background) that the learner brings to the task at hand. A child's knowledge base will determine what information is selected in an illustration. Blystone and Dettling (1990) have documented how students, because of their limited experiences interpreting graphs, will miss pictorial cues in the readings of graphs because they do not bring a high level of sophistication to the task.

Very little research has been carried out in the areas of mental constructs and interpretations of pictures. The literature does not provide answers to such questions as: What is the long term effect of illustrations upon student understanding of specific science concepts? What kinds of conceptual understandings are used when students interpret pictures in informal contexts? How do students apply new learnings when interpreting illustrations and pictures?

Processing Different Kinds of Knowledge

The process of interpreting and examining pictures and illustrations involves a different mental process than the memory of verbal knowledge

(Levie, 1987). This section will summarize three perspectives on how different kinds of knowledge are processed by the learner.

1. Brain research

There has been considerable interest in the relationship between intellect and the brain. Researchers from various disciplines have postulated that there are different "ways of knowing." Focusing on "horizontal faculties," some neuroscientists have cited evidence that indicates the brain has two modes of information processing, one based in the left hemisphere and one in the right hemisphere (Bogen, 1969; Corballis & Beale, 1976). Depending upon the mental task, and partly depending upon the genetic make-up of the individual, one mode of processing will dominant over the other. According to these researchers, the processes that deal with analysis and abstraction, straightforward thought, logical thinking, language acquisition, factual recall (memory), and sequencing tend to be handled by the left hemisphere mode while the right hemisphere mode facilitates perception, imagination, and artistic abilities; helps us to understand dreams and metaphors; and allows us to draw pictures of our perceptions. The right mode fosters the intuitive, the subjective, and time free modes. Although recent research has focused more upon "vertical content" of knowledge, e.g., visual processing in the occipital lobe and language in the left temporal and frontal regions, there is strong evidence that the brain organizes incoming information in a variety of ways and our abilities to use particular processes depends upon prior experiences. Most researchers would argue that the teaching methodology of schools emphasizes those processes associated with the left mode.

2. Multiple Intelligences.

Different representations of knowledge have been addressed by Gardner (1983), who provides a decisive body of evidence for the existence of multiple intelligences, which he calls "frames of mind." Drawing from research on brain-damaged individuals and from personality studies of people in different professions, Gardner defines these "frames of mind" as linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, inter-personal and intra-personal intelligences. These seven modes of intelligence can act collectively or act independently. Gardner's work reflects a departure from previous scientific thinking which viewed intelligence as a unitary capacity, "one linked to the overall mass of usable brain tissue" (Gardner, p. 7).

Spatial intelligence involves the processes of visual memory and visual representation. There is often a discrepancy between knowing something, expressing that body of knowledge verbally, and representing that knowledge in an illustrative or pictorial format. Gardner cites the example of childrens' inability to provide a map or sketch of a place where they have been even though they clearly articulate the directions to where they have been. Individuals who are weak in this form of representation, or reveal inability to trace relationships and to pay attention to detail, tend to rely upon names of features to build understanding (Gardner, 1983).

Spatial intelligence is an assortment of loosely related capacities: the ability to (1) recognize instances of the same element; (2) transform or to recognize a transformation of one element into another, and (3) produce a graphic likeness of spatial information that can operate independently. Mental

imagery and the ability to transform those images appear to be the link that unifies all of these capacities. Rudolph Arnheim, in *Visual Thinking*, argues that "unless we can conjure up an image of some process or concept, we will be unable to think clearly about it" (Gardner, p. 177). Although Arnheim may elevate vision as the sensory system "par excellence," it is important to recognize that imagery is independent of any one sensory mode. Blind persons have demonstrated great capacity for mental imagery and the persistence of spatial intelligence.

3. Other Cognitive Science Perspectives

Cognitive scientists examine the ways that "people come to know" and their research focuses upon the internal processes and the knowledge representations of the learner. The knowledge structures that process and organize information are referred to as schemata, "packets or bundles of information by which we store knowledge" (West, Farmer, & Wolff, 1991, p. 9). From the cognitive scientist perspective, schemata can be categorized as either (1) "state," i.e., mental data structures or the knowledge of knowing how, or (2) "process," i.e., procedures or the ways of processing and organizing information.

Perception is viewed as the "complex process of attaching meaning to events" (West et al., p. 3). Schema serves as the "constructive core" in this process. A schema filters and gives selective attention to incoming information, a procedure that is influenced by prior knowledge. The process of attaching meaning appears to be domain specific depending upon the type of knowledge being manipulated by the learner.

Children's Ideas in Science

Incorporating selected findings from the extensive work on children's ideas in science provides a framework for analyzing how students may interpret illustrations that portray scientific inaccuracies. Numerous studies show that students are very resistant to changing their ideas about natural phenomena. A review of these studies can provide clues into how students may approach interpreting pictures that portray scientific phenomena. This section of the literature discusses (1) the views of selected researchers who examine children's ideas about science, (2) models of children's thinking, and (3) alternate conceptions in the physical and life sciences.

1. Views of Selected Researchers

Much of the work on children's ideas about scientific phenomena has been conducted by researchers from various countries such as the United Kingdom (Bell, 1981, 1985; Driver, 1987; Driver & Erickson, 1983; Driver & Oldham, 1986), New Zealand (Gilbert, Watts, & Osborne, 1985), United States (Posner, Head, & Strike, 1982; Posner & Gertzog, 1982), and Australia (Osborne & Freyberg, 1985; Osborne & Wittrock, 1983; Schollum & Osborne, 1985). Their work reflects a constructivist philosophy of knowledge acquisition that can be summarized as follows:

- a. *Individuals are purposive.* Rather than learning in a passive manner, individuals are seen as actively interacting with their environment to make sense of the world (Driver & Oldham).
- b. *Knowledge is constructed by individuals through social interaction and*

experiences with the physical environment. "An individual cannot 'check' knowledge against some external reality. Our only check is the extent to which our constructions 'fit' our experience in a coherent and consistent way" (Driver & Oldham, p. 110).

c. Knowledge and belief structures influence the meanings individuals construct in a given situation. The amount of learning that takes places depends as much on the learner's present knowledge structures and beliefs as on the characteristics of the learning environment.

d. Constructing meaning is an active process. The learner must be actively involved in making the "connections" between ideas put forth in a learning environment and their prior knowledge. Driver and Erickson (1983) call this process the "dialectic between knowledge in action and propositional knowledge" or the "dialectic between sense impressions and conventional ideas" (Driver & Erickson, p. 45).

e. Understanding is not the same thing as believing. Students may 'generate' a way of seeing something, but not believe it.

f. Learning scientific ideas involves conceptual change. This process may involve either an extension of pupils' conceptions or a major restructuring of their ideas.

Several constructivist and teaching models have been developed, all of which are based on the postulate (Osborne & Wittrock, 1983; Vosniadou, 1988), that children process information according to their own experiences. It is not just experience that determines knowledge but the selective attention given to the experience or the task at hand. This selective attention is dictated by one's preconceptions. Selectivity is part of the process of the learner actively

constructing meaning. Meaning is derived from the interplay of memory, knowledge structures, and incoming sensory information.

2. Models of Children's Thinking

Tasker and Freyberg (1985) found that major disparities exist between teacher and student understandings of several aspects of daily instruction. They found disparities between the:

- a. Ideas children brought to lessons and the ideas that teachers assumed students would bring.
- b. The problem the teacher would have liked the children to investigate and what students took the problem to be.
- c. The activity proposed and the activity performed by the students.
- d. The conclusions reached by students and the conclusions proposed by the teacher.

These findings provide strong evidence that many students' ideas in science are not influenced greatly by classroom instruction. Most of these ideas are acquired quite informally and develop out of students' tendencies to look for meaning and order in the physical world (Bodner, 1986). Children misinterpret scientific and classroom information so that the information will correspond to their existing schemes or schemata (Osborne & Wittrock, 1983). When the knowledge structures used to generate meaning are inadequate, instruction fails to change children's ideas and leads to unproductive outcomes. Often, children's search for meaning is facilitated by sense impressions and intuition (Head, 1986; Driver & Bell, 1986; Rowe, 1990). Gardner (1991) refers to the intuitive learner as the "unschooled mind," suggesting that ideas formulated in

early life about the workings of the natural world tend to surface throughout life, especially when the learner confronts new situations. Sense impressions, or the understandings of the "unschooled mind," bring the learner into direct conflict with formal science. Unlike the claim of Thomas Huxley that science is "organized common sense," much of science defies everyday experiences and runs counter to the intuitive knowledge of the child. For the student, this often generates a conflict between school science and "real science," i.e., the science learned in a classroom versus the alternate conceptions that students bring into a learning situation. Scientific models of the solar system, for example, do not easily match our observations that the sun seems to revolve around the earth. Sense impressions, or intuitive knowledge, do not provide the mental structures for the understanding of concepts such as molecular theory, electrical current, or static electricity.

Vosniadou (1988) postulates that students have three models of thinking when interacting with the physical world. Her conclusions were based on a study of first, third, and fifth grade students' knowledge acquisition in astronomy. The population sample consisted of sixty children from the first ($n=20$), third ($n=20$), and fifth ($n=20$) grade. The models are:

(1) *Phenomenal*. Ideas that come out of experiences with the natural world and mirror the restraints of the physical world, e.g., the world is flat, the sun goes down and the moon goes up (to explain day night cycle). When a learner of any age is presented with unfamiliar concepts, intuitive ideas often surface as the most sensible explanation.

(2) *Assimilatory*. A combination of phenomenal and scientific models. A student may accept that the earth is a sphere but contend that there is a flat

middle or that the "flat" earth is surrounded by a sphere. Investigations of advanced models of assimilation provide valuable insights into the existence of experiential or phenomenal beliefs.

(3) *Scientific*. The acceptance of a scientific model.

Vosniadou sought to determine with what consistency students applied these three models when learning astronomy concepts. Vosniadou found 80-85% consistency of responses during interviews, with students using the same model of thinking when only one concept was examined. When more than one concept was explored, such as day/night cycle and rotations of the earth and moon, the consistency of model thought was less than 50 percent. For example, a student may agree that the earth rotates yet insist that the "earth finds the moon at the night spot."

Vosniadou contends that the set of ideas that children have about the natural world does not constitute an hypothesis or a theory but are subject matter specific. Students will not use their mental models that is based on one concept to form a generalization that applies to another concept. This conclusion agrees with the findings of other researchers (Confrey, 1990).

Vosniadou suggests that a misconception begins when children are confronted with models that contradict phenomenal beliefs. Children do not want to believe that the adult is wrong but they are unable to reconcile the new information with their old mental models. Children, rightly or wrongly, assume that they have "misunderstood" but try to assimilate the new information into existing mental structures. A child may accept the adult notion that the earth is round, yet insist that a person cannot reach the end of the earth because it is too high.

It is interesting to consider how two-dimensional pictures depicting earth-sun revolution, sunsets, or the solar system may reinforce children's notions that the sun goes down and disappears, or that the earth is flat.

3. Studies on Alternate Conceptions

When a student looks at a illustration or any visual image, the student is affected by a "pre-perceptual filter." Studies that have investigated alternative conceptions in science have provided valuable clues for understanding the 'filter' mechanisms. Most studies on alternate conceptions have verified that, despite instruction, the preconceptions that students hold at an earlier age do not necessarily disappear in later years. Alternate conceptions described in this study were selected for their relationships to the content of the illustrations used in this study.

A. Alternate conceptions in the physical sciences

Stephans, Beiswenger, and Dyche (1986) investigated student ideas about sink/float concepts. A sample of 184 students from primary, intermediate, and junior high and 52 college students enrolled in an elementary education class.were interviewed. Physical objects were used in the interviews to help researchers examine how students related the factors of mass, volume, density, water pressure, and buoyancy to sinking and floating. Interviewers asked students if a particular object would float and often asked follow up questions such as "Does wood always float?" The findings of this study showed little difference in understandings of float and sink between the grade levels. While older students and college students replaced simpler terms used by elementary

students such as "light," "heavy," "weight," with terms such as "density," "physical properties," "surface tension," and "mass," the terms were often used inappropriately when students responded to researcher's follow up questions. Students did not differentiate between mass, density, and weight and used all three terms interchangeably to explain that "heavier objects sink." When interviewers asked ninth grade students why crumpling a piece of aluminum foil causes it to sink, 70% responded, with the statement, "Crumpled foil is heavier." Student's incomplete understanding of density fostered even greater confusion about conservation of matter. Junior high students seemed to be especially concerned about using terminology that would please the teachers and researchers.

There have been several studies that confirm the presence of naive theories about falling objects (Champagne, Klopfer & Anderson, 1980; Green, McClosky & Caramazza, 1980). The notion that heavier objects fall faster than lighter objects persists despite instruction. Champagne et al. (1980) examined → the ideas of college freshman in an introductory physics class. Seventy percent of those studied had taken high school physics, some for two years. In these courses, students were exposed to Newtonian mechanics which specifies that all objects fall at the same rate in a vacuum. Despite this background, eighty percent of the sample held on to the notion that heavier objects will fall significantly faster than lighter objects even when all other variables are controlled.

Students' theories about motion are derived from years of experience with moving objects and serve students well in helping them interpret the natural world. Students' ideas about motion are organized differently in their memory

than scientists' schemata. The table below (Table 1) delineates the differences between a student theory and a scientific explanation for falling objects (Champagne & Klopfer, 1985).

Table 1

Student and Scientist Schemata for falling objects.

Student Schemata	Scientist Schemata
1) Heavier objects fall faster than lighter objects.	1) All objects fall at the same rate.
2) Velocity is proportional to force.	2) Acceleration is proportional to force.

Presence of these schemata was demonstrated in a study by Champagne and Klopfer (1985) that involved equal numbers of college, high school and middle school students ($n = 500$). Observations were made of student interpretations of physics demonstrations. After the instructor showed and manipulated the physical apparatus, students were asked to predict the outcome of the demonstration and give an explanation for their prediction. After the demonstration, students discussed the outcomes and talked about the conflicts between their observations and their predictions.

On one task (figure 1, #1), students were asked to compare the rates that a plastic and aluminum block, identically shaped, would fall to the ground from one meter. Eighty percent of the students predicted that the aluminum block

would fall faster. Even though the demonstration clearly showed that the blocks fell to the ground at the same time, 40% of those students who predicted the heavier object would fall faster observed that the aluminum block fell faster. After several observations of the same demonstration, students still argued that if the blocks were dropped from a longer distance, the heavier one would fall faster. Students would call up knowledge learned about Galileo's assertions that a gold coin would fall faster than a feather but selectively forget to apply Galileo's claim that both objects would fall at the same rate in a vacuum. They forgot that part of the story which did not coincide with their schema.

#1

#2

Figure 1. Demonstrations of falling objects
(Champagne & Klopfer, pp. 183, 185)

In another task, students observed the motion of a block being pulled along a horizontal plane by a bucket suspended over a fixed pulley (figure 1, #2). The students observed that the block speed was five times faster at point B than at point A. Students reasoned that the increased speed of the block at point B was caused by the increased weight of the bucket as it approached the ground. In their schema of "lower to the ground is heavier," they argued that the bucket was five times heavier at location *b* than at location *a*. When students measured the weight of the bucket and discovered that the bucket's weight did

not change, they argued that there was no weight difference because the distance between *a* and *b* was too small.. Only after comparing the weight of the bucket at the ceiling and then close to the floor did students consider the proposition that weight is not altered by its distance from the floor. Only at this point were the students willing to examine the validity of their own lower-is-heavier view.

B. Alternate Conceptions in Biology.

Many illustrations found in children's books anthropomorphise animals and contain scientific inaccuracies. We have little knowledge of how these inaccuracies may contribute to reinforcing and fostering misconceptions. Investigating studies that examine alternative understandings in the biological sciences provides a framework for understanding how students may interpret visual images that have a life science connotation.

Some of the findings in alternative conceptions related to biology have parallels to the work conducted by Piaget (1929). This section of the review will include (1) a synthesis of Piaget's findings on animism and (2) recent studies of alternate conceptions in biology.

1. Piaget's work on animism

Piaget investigated children's tendencies to apply animate or alive characteristics to inanimate objects, a phenomenon he labeled "animism." Initially, Piaget was curious about the presence, or lack of presence, of the notion of mind in the child's scheme. His studies led him to conclude that children undergo four stages of animism with all stages of animistic thought

organized around the notion of motion. Piaget 's stages of animism are:

Stage I. All things that are active are conscious.

Stage II. Consciousness is only attributed to things that move.

Stage III. Distinctions are made between movements made by the object itself and movements external to the object.

Stage IV. Consciousness is attributed only to the animal world.

In the first two stages Piaget found that children do not state that the object is conscious but at any given point the child will ascribe awareness to the object. For example, a child may not attribute any human characteristic to the sun but when asked, "can the sun feel when you pinch it," the child answers, "yes." If there is an activity, i.e., motion, it is viewed as purposeful and therefore conscious. The challenge for Piaget becomes "how the child comes to conceive an unconscious action and to dissociate the notion of the actions from that of consciousness of the action rather than why action and consciousness appear necessarily connected" (p.185). This statement presents an interesting parallel with the current work of conceptual change theorists who focus on the conditions that cause the learner to approach an experience with a new schemata (Posner, Strike, & Gertzog, 1982; Watson & Konicek, 1990).

Piaget conducted some of the first work on children's concept of what is alive and not alive and not surprisingly, found similar stages of concept development as in animism. Piaget suggested that children undergo four stages of thought in relation to the concept of "life." Underlying all of the stages is the notion of causality and movement.

Stage I. Something is alive if it has a function (6-7 years old).

Stage II. Alive is defined by any kind of movement, not just spontaneous (8-9 years old).

Stage III. Something is alive if it engages in spontaneous movement (9-11 year old).

Stage IV. Life is restricted to plants and animals (over 11 years old).

Piaget found that 11 year old children believe that fire is alive "because it gives us light." Many eight year olds believed that clouds blow wind but Piaget cautions against a conclusion that children then believe that the cloud is alive. Rather, a child may attribute aliveness to the wind because it is responsible for the movement of the cloud. According to Piaget, the use of everyday language and expressions, such as "the wind blows," fosters confusion with children between the ages of 5 and 10 because they are not capable of making adjustments between the spoken word and implicit meanings. The persistence of a movement schema helps explain the finding that three-quarters of all 11-12 year olds interviewed by Piaget had not reached stage four.

The use of animism is not a belief system nor does it reflect a systematic way of approaching the world. In fact, when a child becomes reflective and approaches the concept of life in a systematic manner, Piaget states that the child discards animism.

2. Recent studies

Much of the research investigating alternate conceptions in the biological sciences focuses upon children's understandings of everyday words such as living and animal (Bell, 1981; Tamir et al., 1981; Stephans, 1985). It often is assumed by teachers that children adhere to the commonly accepted definition

of animal. Bell's study (n= 39) indicates that children have different criteria than biologists for deciding what is an animal. A biologist would define an animal as being heterotrophic (eats food), displaying movement, possessing sense organs and containing a cell structure. Children, however, focus upon criteria such as animals have legs, they move, they breathe, they have a brain, and they live on land. Children have a much more restricted view of what actually is an animal. In one study cited by Bell, 50% of seniors in a biology class did not consider a spider to be an animal. Younger children tended to restrict their grouping of animal to four-legged creatures that lived on the land.

Tamir, Gall-Choppin, and Nussinovitz (1981) conducted research with adolescent students that asked the following questions: (1) How well do students differentiate between living and non-living? and (2) What criteria do students employ in classification? Many findings in this study reinforce Piaget's work on animism. Unlike scientists, children are not consistent in their applications of life concepts to inanimate objects. Many students (34%) thought that seeds were not alive and did not consider the inconsistency of feeling that living things (85% thought seedlings were alive) can come from an object they perceived as non-living. Embryos did not fall into an "alive" schema. Along with Bell's studies (1981, 1985), these findings indicate that students do not perceive the commonality among all living things. Classroom use of metaphors (fire moves, the fire is growing) may also contribute to student misconceptions about what is alive and not alive.

Using Piagetian assessment techniques, Stephan (1985) interviewed thirty fifth graders concerning 11 living and non-living objects. The living objects included a leaf, a tree, a flower and a worm while non-living consisted of sun,

candle, bicycle, wind, volcano, water, and lightening. Interviews lasted 15 minutes and followed a set format beginning with an initial question "Is the Sun alive?" and then followed up with "Why do you think so?" After the list of objects was completed, students were asked "What does it mean to be alive?"

Students had been exposed to textbook lessons on the concept of living and non-living for five years. The results indicated that many fifth graders attribute living qualities to non-living objects, such as the sun (53%), water (62%), lightening (82%), wind (79%), and volcano (76%). Most students focused upon only one attribute of the object and in most cases, focused upon whether there was an action associated with the object. If the student perceived an action, e.g., lighting can shock you, then the object was alive. The findings suggest that students were not successful in applying their textbook knowledge, and more importantly, reveal the importance of giving students the opportunity to express their views so that conceptions can be identified.

Trowbridge and Mintzes (1988) conducted a study of student's alternative conceptions about animal classification to assess whether the same conclusions and generalizations gathered in smaller studies incorporating interview techniques would be found with a larger group ($n = 468$). The study was cross-age and included fifth graders (100), tenth graders (80), non-science majors level (100) and biology majors (88). Twenty-two test items were divided into three categories. Note that one of the categories used pictures to assess knowledge. The questions that accompanied each category are listed below.

PICTORIAL ITEMS (line drawings of animals): Is this an animal? How sure are you of your answer? Does this animal have a backbone?

FREE RESPONSES: List the names of ten animals. What is an animal? Tell me what you mean when you use or hear the word animal?

VERBAL QUESTIONS: Circle the animals that have a backbone. Circle the animals that do not have a backbone.

These questions parallel items that were used in interviewing strategies in previous studies by the same researchers. A coding system was used to quantify the free-response data. The findings of this study parallel some findings in past studies and depart from others. Student answers to the free-response items reveal no clear developmental patterns but reflect a diverse mix of correct and incorrect views about animals. In all student groups, a wide range of attributes were given such as: animals are alive; they have appendages; they live outside in the woods; they eat; animals have hair, fur, and covering. Seven of the twelve most mentioned traits were common to all groups. As in Bell's study (1981), students tended to hold a restricted view of animal, with most students listing vertebrates as animals. Student schemata that defined animals as having appendages or coverings (shells) interfered with their classification of animals, such as spiders. Only 44% of junior high, 55% of high school, and 48% of non-majors correctly classified the spider.

Summary

The literature gives little attention to students' abilities to detect inaccuracies in pictures or how conceptual understanding relates to interpretations of illustrations. However, numerous insights from research on children's thinking are useful when analyzing the responses to the instruments

used in this investigation.

Cognitive science provides explanations for how children build knowledge from experiences with the world around them. Different "ways of knowing" and of processing information are recognized and consider distinctions between verbal and pictorial processing. The literature documents the existence of children's ideas in science which are very resistant to change. Many of these ideas are related to concepts represented in the illustrations used in this study.

CHAPTER III

METHOD

Introduction

This study identified and compared students' abilities to detect scientific inaccuracies in selected illustrations. Although there is evidence that pictures increase interest in print material and may enhance long term memory of text information (Peeck, 1972), almost no work has investigated student interpretations of accuracy in illustrations.

Students in the 3rd, 5th, and 8th grades were asked to determine whether inaccuracies existed in a set of illustrations typically used for motivational purposes within instructional materials. Illustrations were grouped into five categories. Hypotheses were made about student responses to each illustration. Student identifications and descriptions of errors in the illustrations were compared to responses given on an objective assessment designed to test for knowledge of the science concepts represented in the illustrations.

Research Questions

For purposes of review, the research questions addressed in the study are stated again:

1. Can students detect scientific inaccuracies in illustrations?
2. Are there significant differences between responses given by third, fifth, and

eighth grade students on the two kinds of assessment?

3. What are some key characteristics and patterns of understanding revealed by the responses of third, fifth, and eighth grade students asked to identify scientific inaccuracies in illustrations?
4. Are patterns of understanding revealed by student responses to illustrations different from those revealed by responses to an objective test that assesses the same content knowledge?

Research Population

The study was carried out with groups of third, fifth, and eighth grade students in the Monterey Peninsula Unified School District. The Monterey Peninsula Unified School District is a medium sized school district (14,460 students) that serves the communities of Marina, Fort Ord, Seaside, and Monterey, California. There are 16 elementary schools, 4 middle schools, 2 large high schools, and 2 continuation high schools. Over 35% of the students come from military families who are serving at Fort Ord, the Naval Post Graduate School, and the Defense Language Institute. At some schools, the student turnover rate is 30% per year. The profile of students varies from school to school. The research population reflects an ethnic and socio-economic diversity that mirrors the public school population in the state of California. Listed below are some socio-economic characteristics for each school.

SCHOOL SITE	LOCATION	SOCIO-ECONOMIC CHARACTERISTICS
SITE A	K-5 Naval Post Graduate School Housing	High number of parents with post graduate degrees Large number of officers
SITE B	K-5 Fort Ord (on base)	Enlisted army personnel lower / lower-middle class income levels
SITE C	K-5 Marina	Equal number of civilian and army parents Lower middle income levels Non-professional jobs
SITE D	6-8 (Middle school) Marina	Equal number of civilian and military families Family income range from lower to middle income Higher percentage of Asian families than other schools in sample

Three elementary schools (K-5) and one middle school (6-8) were involved in the study. Three hundred seventy students participated in the study but only 331 students completed both assessments. The final sample included 6 classes of third grade students (n =113), 6 classes of fifth grade students (n = 107), and 6 classes of eighth grade students (n =113). The ethnic breakdown for each school and respective grade level (s) participating is listed in Table 2.

Table 2

Ethnic Makeup of School Sites

School	Grade	Spanish (%)	other white (%)	Black (%)	Asian (%)	Pacific Island (%)
SITE A	3rd	4.8	79.2	6.7	7.4	1.8
SITE B	3rd 5th	14.2	44.3	29.1	1.6	10.0
SITE C	5th	9.7	34.4	31.5	12.6	10.8
SITE D	8th	11.1	37.9	17.2	21.9	10.8

Three elementary science teachers and one middle school science teacher participated in the study on a volunteer basis. At school sites A, C, and D, all classes for each designated grade level participated. To equalize the number of students at each grade level, 2 of 3 fifth grade classes and 3 of 4 third grade classes were chosen at school site B. Classroom teachers at each grade level determined which classes participated in the study. All classes involved in the study from site B were representative of the larger school population.

For the last six years, all elementary students in 1st through 5th grades have received a semester of science lab from a credentialed elementary science specialist. For that one semester, students receive between 30 to 60 minutes of science lab instruction per week in 1st through 3rd grades and between 40-90 minutes of instruction per week in 4th through 5th grades.

Science lab engages students in hands-on activities that facilitate development of process skills and introduce students to science concepts that coincide with guidelines set by the *California Science Framework*. Listed below are science lab units for 3rd through 5th grade students.

GRADE LEVEL	UNITS TAUGHT
3rd Grade	states of matter, habitat, measurement, magnetism
4th Grade	electricity, rocks and geology, adaptation
5th grade	ecology, properties of matter, kitchen chemistry, conservation

The amount and quality of science taught varies dramatically when students are not attending science lab. Generally, elementary students receive very little hands-on science instruction in the regular classroom.

Middle school students take one semester of general science in 6th grade, one semester of life science in 7th grade, and one semester of physical science in 8th grade.

Description of Instruments

1. Survey of text and supplementary materials

A primary intent of the study was to gather information from a large number of students concerning their ability to detect scientifically inaccurate features in illustrations. A preliminary survey of three sources of illustrations was conducted to determine whether there was a pattern of scientific inaccuracies in

published materials. These three sources were textbook and supplementary materials, school literature books, and cartoons.

Some research findings have documented misconceptions fostered by textbooks (Barrow, 1990). Elementary science textbooks and supplementary materials were surveyed to determine if inaccuracies could be found in materials used regularly in classrooms. The Harcourt Brace Jovanovich (HBJ), Silver Burdett, and Holt textbook series were examined because they are three of the most commonly used science textbook series adopted by California public schools for the K-6 level (1985 adoption). The *AIMS* series, (Activities that Integrate Math and Science), and drafts of a new *Life Lab* curriculum, activities which teach science concepts through a gardening program, were also examined for scientific inaccuracies in illustrations. The following are the findings from the survey of text materials.

A. Very few inaccuracies were found in textbook illustrations.

The illustrations in textbooks were included primarily for instructional purposes. There were some discrepancies between illustrations and accompanying text. For example, in a first grade text, a picture of three jars showed one with no lid, one with a lid, and one filled with water and no lid. The accompanying question was, Which jars have air in them? From a scientific viewpoint, all of the jars could contain air, but it is unlikely that that was the student response expected. Illustrations that depicted weather phenomena, such as those related to seasonal changes, and the solar system did not correspond to the accompanying text in a clear manner. Although this is of academic interest, the mismatch between illustrations and text was not chosen as an area of concern in this study.

B. There were inaccuracies found in several supplementary materials, such as student worksheets, where the illustrations were used for motivational purposes on worksheets designed to elicit written responses. Examples of this kind of illustration were fish that exhale bubbles from their mouths, clouds that blow air, insects with four legs, animals (in most occasions, invertebrates) with anthropomorphic features (such as big eyes), and flowers with happy faces. Several examples of this type of illustration were found in AIMS materials (K-1 series, 1986 edition) and on fewer occasions, in textbook supplementary materials. Some of these illustrations had cartoon-like qualities.

Three hundred literature books were browsed for illustrations that reinforced misconceptions and modeled scientific inaccuracies. Many literature illustrations that have obvious inaccuracies, as in *Magic School Bus Goes Inside the Earth* (bus driving through the center of the earth), *Cloudy with a Chance of Meatballs* (food falling from the sky), are meant to foster the student's imagination, rather than serve as models of scientific accuracy. One title was found that included dinosaurs and humans interacting together: *Dinosaur Bob and his Adventures with the Family Lizard*. Although the author or illustrator's intent for displaying inaccuracies in such literature as Winnie the Pooh (Winnie the Pooh being lifted by the balloon) is not clear, the illustration served as good examples of scientific inaccuracies that could be incorporated into an illustration assessment.

Comic books are a significant source of reading material for elementary students. A small number of comic books (Bugs Bunny, Loony Toon comics) were examined to determine what type of cartoon sequences exemplify misconceptions or what sequences could be incorporated into an illustration

booklet for assessment purposes. Examples found included depictions of Roger Rabbit running in mid-air and comic characters falling in an improbable manner.

2. Development of the Instruments

From these three surveys, a set of illustrations was selected. A reading specialist, a science educator and a professor of science education advised on appropriateness of the illustrations for assessment. A pilot study was conducted with two fourth grade classes and a group of student teachers from a science methods class at San Jose State University. Fourth grade students were chosen for the pilot because they represented students within the grade span studied yet were not part of the sample in the actual study. Two illustrations used in the study were selected from AIMS materials (ladybird beetle, spider), while the remaining were given by anonymous contributors. Illustrations were re-drawn and questions rephrased based upon information received from the pilot and consultation with a science education professor. The illustrations were categorized and divided into two sets, "A" and "B." One illustration in set B was later omitted because of its confounding design.

The following were the set of illustrations chosen for the study. The actual student booklet size was 4" x 8 1/2". An explanation of the misconception(s) represented () and considerations for selection are given.

BOOKLET A

ILLUSTRATION

LADYBIRD BEETLE

DESCRIPTION

There are several scientific inaccuracies in this illustration. The Ladybird beetle has only four legs instead of six. Flowers and leaves of plants do not have to be watered from their topside. The animals have anthropomorphic features. Will students detect a variety of inaccuracies? What will be the most common response? How often will students detect that the ladybird beetle has only four legs?

CAVEMAN AND
DINOSAUR

Dinosaurs became extinct 100 million years before humans appeared on the planet. Elementary students have a difficult time with the chronology of events, especially related to geologic time. Do students recognize that dinosaurs and humans did not coexist?

FISH

Fish do not exhale air. This illustration is a fairly common depiction of fish in literature, cartoons and in decorative motifs in popular culture. What kinds of understanding do students have of gills, of how air is exchanged in a fish and of differences between respiratory systems of fish and air breathing animals?

CLOUDS

Clouds do not produce wind nor does wind come from clouds. Clouds do not have human features. How many students will focus upon the anthropomorphic features compared to the inaccuracy of clouds being a source of wind? Do students' responses reflect misconceptions about how wind is generated?

WINNIE THE POOH

A balloon full of air cannot lift a stuffed animal. What are student explanations for how an object could be carried by a balloon? Do they apply any scientific concepts in their written responses such as "the balloon would need helium to lift the object" or the balloon would have to act like a hot air balloon?"

BOOKLET B

SPIDER

Spiders do not have three body parts.

Spiders have eight legs. Can students transfer factual knowledge about spiders, e.g., spiders have eight legs, when asked to detect inaccuracies in this illustration? Will students distinguish between spiders and insects?

POLAR BEAR AND PENGUIN

Penguins live in the South Pole while polar bears live in the North. Do

students know that polar bears and penguins live in different hemispheres? Do students think that polar bears and penguins coexist but not as predator and prey?

WORM

Worms do not have human-like eyes.

To what extent are students aware of this inaccuracy? Previous research has documented the frequency of misconceptions that students have about invertebrates. What confusions exist among the students related to body parts of a worm?

ROGER THE RABBIT

In the presence of gravity, an object in motion will not fall as depicted in this illustration. This kind of scientific inaccuracy is common in cartoons. Do students think that real objects can fall in this manner?

A parallel set of objective questions for a second assessment, focusing on the same science content as addressed in the illustrations, was developed using a combination of multiple choice, true/false, and cued complete-the-picture format. (see Appendix B).

Administration of Assessment Tools

1. Booklet of Illustrations

All students were given parent permission slips for consent to participate in the study. These were returned to respective classroom teachers. Every participating science teacher received a five minute videotape, produced by the researcher, that provided instructions for the students and a set of teacher instructions for administering the study (See Appendix B). The videotape was used as the introduction for the lesson for all classes at Site A, C, and D. The five classes at Site B, which were assessed by the researcher, did not view the videotape but observed the same demonstration as presented on the videotape. Before students watched the videotape, the instructor passed out

numbered illustration booklets to facilitate following the instructions on the tape. Even numbered booklets corresponded to matrix A and odd numbered booklets corresponded to matrix B. Each matrix contained five illustrations and a sample page with an insect illustration (see Appendix A). A picture of a dog was also used as a sample illustration. For each illustration the following questions were asked:

- 1) Would a scientist say that this is a correct picture of a _____?
- 2) If your answer is no, mark a circle on the part of the picture that is not correct.
- 3) Explain your answer.

Before beginning the exercise, students were encouraged to look for more than one inaccuracy. All students were able to complete the booklet within a twenty minute period.

2. Second Assessment Tool

A second assessment was given to students three weeks after the picture assessment. The purpose of the second phase of the study was to compare the student responses on a traditional type of assessment of content knowledge (true-false questions) to the open ended responses that were given for the illustrations. To facilitate comparison between the two assessments, students were given the same test number as recorded on the first assessment. The objective assessment consisted of ten items (see Appendix B). Five statements were true-false items, five statements asked students to complete a drawing, and one item was a multiple choice question. The ten items in science content

correlated to the ten illustrations in the first assessment. All students in groups A and B were tested for all ten items.

A week long spring break delayed the administration of the second assessment. Most third and fifth grade students took the second assessment three weeks after the first assessment. A delay in the administration of the first assessment to eighth grade students (teacher not able to obtain VCR) resulted in only a ten day gap between the administration of the two tests.

Originally, item #1 stated, "Caveman hunted dinosaurs and helped cause them to become extinct. After examining the responses from the first three classes (3rd grade students), it was evident that item #1 should be redesigned. Item #1 was divided into two questions, "Caveman hunted dinosaurs" and "Caveman helped cause dinosaurs to become extinct." Three third grade classes and two fifth grade classes were tested a second time on item one using the above example. All other classes were given the second assessment after the above change had been made.

Hypotheses

1. General Hypotheses

The general hypotheses addressed by this study are:

- a. Fewer than 50% of students in third, fifth, and eighth grades demonstrate an ability to detect scientific inaccuracies in illustrations.
- b. Students in higher grades are more able to detect scientific inaccuracies in illustrations than students in lower grades.

- c. Knowledge demonstrated by students inspecting pictures is different from knowledge demonstrated by responding to objective tests.

2. Specific Hypotheses

Hypotheses that refer to specific illustrations and test items have been categorized into five groups. Criteria for the grouping was based upon whether detecting a specific inaccuracy required factual recall (Group 1), conceptual understanding (Groups 2,3,4,) or higher levels of thinking (Groups 4,5).

GROUP	ILLUSTRATION
1. Body Parts	Spider, worm and ladybird beetle
2. Interaction: Time and Place	Polar bear/Penguin, Dinosaur and Caveman
3. Interaction: Cause and Effect	Clouds
4. Biological Processes	Fish
5. Physical Laws	Winnie the Pooh, Roger Rabbit

Hypotheses for Category 1. Body Parts

- a. More eighth grade students detect incorrect number of legs on the ladybird beetle than do third grade students.
- b. More eighth grade students tested detect incorrect number of legs on the ladybird beetle than do fifth grade students.
- c. More fifth grade students tested detect incorrect number of legs on the ladybird beetle than do third grade students.

- d. More students draw the correct number of legs on a ladybird beetle than detect inaccurate number of legs in an illustration.
- e. More students draw the correct number of legs on a spider's body than detect incorrect number of legs in a illustration of a spider.
- f. Fewer than 50% of all students tested detect the incorrect number of legs in a spider illustration.
- g. More students tested detect the incorrect number of legs than inaccurate number of body parts in a spider illustration.
- h. Third grade students, when compared to fifth grade students, demonstrate characteristic differences in their responses to a spider illustration.
- i. Fifth grade students, when compared to eighth grade students, demonstrate characteristic differences in their responses to a spider illustration.
- j. More students tested draw correct number of legs on a spider's body than detect incorrect number of legs in an illustration.
- k. When shown an illustration with a worm with human eyes, less than one half of students tested indicate that worms do not have human eyes.
- l. Third grade students, when compared to fifth grade students, demonstrate characteristic differences in their responses to an illustration that shows a worm with human eyes.
- m. Fifth grade students, when compared to eighth grade students, demonstrate characteristic differences in their responses to an illustration that shows a worm with human eyes..
- n. Eighth grade students, when compared to third grade students, demonstrate characteristic differences in their responses to an illustration that shows a worm with human eyes.

Hypotheses for Category 2. Interaction: Time and Space

- a. More than 50% of students tested do not demonstrate the understanding that humans and dinosaurs lived at different times.
- b. More fifth grade students than third grade students demonstrate an understanding that humans and dinosaurs lived at different times.
- c. More eighth grade students than fifth grade students demonstrate an understanding that humans and dinosaurs lived at different times.
- d. More students tested correctly respond to true-false questions about humans interacting with dinosaurs than detect an inaccurate interaction between humans and dinosaurs in an illustration.
- e. More than 50% of students tested do not indicate that polar bears and penguins live in different areas of the world.
- f. Third grade students, when compared to fifth grade students, demonstrate significant differences in their responses to an illustration showing a polar bear and penguin.
- g. Fifth grade students, when compared to eighth grade students, demonstrate significant differences in their responses to an illustration showing a polar bear and penguin.
- h. Eighth grade students, when compared to third grade students, demonstrate significant differences in their responses to an illustration showing a polar bear and penguin.
- i. Most students answer "true" when given the question, "A polar bear eats penguins for food."

Hypotheses for Category 3. Interaction: Cause and Effect

- a. More third grade students, when shown a cloud illustration, detect that the cloud does not have a face than detect that a cloud does not blow air.
- b. More fifth grade students than third grade students detect that a cloud does not blow air when responding to a cloud illustration.
- c. More eighth grade students than fifth grade students detect that a cloud does not blow air when responding to cloud illustration.
- d. More students answer that wind does not come from clouds in a true-false assessment than detect this inaccuracy in a cloud illustration.

Hypotheses for Category 4. Biological Processes

- a. More than 50% of students tested do not identify an illustration showing a fish blowing bubbles through its mouth as scientifically inaccurate.
- b. Fifth grade students, when compared to third grade students, demonstrate no significant differences in their responses to an illustration showing a fish blowing bubbles through its mouth.
- c. Eighth grade students, when compared to fifth grade students demonstrate significant differences in their responses to an illustration showing a fish blowing bubbles through its mouth.
- d. More students tested answer false to the statement, "A fish exhales air through its mouth," than detect the inaccuracy of a fish blowing bubbles through its mouth in an illustration.
- e. Third grade students, when compared to fifth grade students, demonstrate significant differences in their response to the true-false question, "Fish exhale air through the mouth."

f. Eighth grade students, when compared to fifth grade students, demonstrate significant differences in their response to the true-false question, "Fish exhale air through the mouth."

Hypotheses for Category 5. Physical Laws

a. Third grade students when compared to fifth grade students, demonstrate significant differences in their responses to an illustration that shows Winnie the Pooh being carried by a balloon.

b. Fifth grade students, when compared to eighth grade students, demonstrate significant differences in their responses to an illustration showing Winnie the Pooh being carried by a balloon.

c. More than 50% of third grade students answer that the statement, "The balloon can lift up the stuffed animal," is true.

d. Three-fourths of fifth and eighth grade students answer that the statement, "The balloon cannot lift up any of the objects," is true.

e. More fifth grade students than third grade students demonstrate scientific understanding in their responses to an illustration showing Roger Rabbit running off a cliff.

f. More eighth grade students, than third grade students demonstrate more scientific understanding in their responses to an illustration showing Roger Rabbit running off a cliff.

g. More students correctly draw the path of a falling car off a cliff than to indicate that a cartoon character cannot fall at a right angle when running off a cliff.

DATA ANALYSIS

For purposes of organizing data, a data table was developed to tabulate the results from each item in the assessment booklet and the objective test. Other columns added to the grid correlated to whether students detected specific inaccuracies or demonstrated understanding of specific science concepts. The following fields and codes were used to compile the data.

FIELDS	EXPLANATION (Code response)
student #	
sex	
grade	
school	
ladybird beetle	0 - accurate 1 - inaccurate
# of legs	0 - detect inaccuracy in legs 1 - does not detect wrong number of legs
responses	0-3 - # of inaccuracies mentioned
#2 ladybird beetle	0 - draws correct # of legs 1- draws incorrect # of legs
dinosaur	0- accurate 1- inaccurate
interaction	0- does not detect human/dinosaur inaccuracy 1- mentions human/dinosaur inaccuracy
#1a	0- true 1- false

#1b	0- true 1-false
fish	0- illustration accurate 1-illustration inaccurate
blow bubbles	0- does not state blowing bubbles is incorrect 1- states that fish do not blow bubbles
#9	0- statement true 1- statement false
cloud	0- illustration accurate 1- illustration inaccurate
face only	0- does <i>not</i> state that face is inaccurate 1- states that face is inaccurate
#of responses	0-3- # of inaccuracies stated
blow air	0- does <i>not</i> state that blowing air is inaccurate 1- does state that blowing air is inaccurate
#3	0- true statement 1- false statement
Winnie	0- illustration is correct 1- illustration is not correct
cartoon response	0- uses cartoon for justification 1- does not use cartoon for justification
scientific response	0- lack of scientific understanding 1- answer demonstrates science understanding
#4	may respond #1-5
spider	0- illustration accurate 1- illustration inaccurate
legs	0- states spiders has incorrect # of legs 1- does <i>not</i> state that spider has incorrect # of legs

body parts	0- states that spider has wrong # of body parts 1- does not state that spider has wrong # of body parts
#10	0- draws correct # of legs 1- draws incorrect # of legs
#10a	0- draws legs on right body part. 1- draws legs on incorrect body part
polar bear	0- illustration accurate 1- illustration inaccurate
habitat interaction.	0- does not mention inaccuracy of polar bear /penguin inaccuracy 1- mentions inaccuracy of polar bear/penguin detects inaccuracy yes/no
other response	0- provides other explanation for no response 1- does not give another explanation
# 5	0- true 1- false
worm	0- illustration accurate 1- illustration inaccurate
detect eyes	0- detects human eyes inaccuracy 1- does not detect eyes as inaccurate
#7	0- does not draw eyes 1- draws eyes on worm
#7 other	0- does not draw any other body parts 1- draws some other body part
rabbit	0- illustration accurate 1- illustration inaccurate
cartoon answer	0- mentions cartoon as justification for answer 1- does not mention cartoon as rationale
rabbit/scientific response	0-answer shows scientific understanding 1- does not show scientific understanding

#6	0-draws accurate model of falling car 1- draws inaccurate model of falling object
#8	0-yes 1-no
#12	0 -yes 1-no

Fields such as rabbit, spider, and cloud refer to the specific illustrations in the assessment booklet. Numbered items, e.g., 10, 11b, refer to questions in the objective assessment. Fields labeled "scientific response" refer to how often students used scientific explanations to explain their yes or no response.

The data was organized using the Stat View TM statistical program for the Macintosh computer created by Brain Power Inc, Calabasas Ca. Contingency tables were determined for:

- 1) Responses to all illustration booklet items across the grade levels.
- 2) All items in the objective assessment that correlated to a specific illustration (Items #8 and #10 were excluded).

Significances in differences in responses by grade level were measured by using the Chi-square analysis and related contingency tables.

CHAPTER IV

Results

Introduction

For purposes of reviewing the results of this study, the illustrations tested are divided into five categories.

1. BODY PARTS
2. INTERACTION: TIME AND PLACE
3. INTERACTION: CAUSE AND EFFECT
4. BIOLOGICAL PROCESSES
5. PHYSICAL LAWS

Each category is addressed separately. For all categories, each analysis relates to the three general hypotheses:

- a. Fewer than 50% of students in third, fifth, and eighth grades demonstrate an ability to detect scientific inaccuracies in illustrations
- b. Students in higher grades are more able to detect scientific inaccuracies in illustrations than students in lower grades.
- c. Knowledge demonstrated by students inspecting pictures is different from knowledge demonstrated by responding to objective tests.

The responses given to the illustration assessment and responses given to the objective assessment are treated in separate tables (#3 through #17). The statements that students wrote, when asked to explain their answers as they marked an illustration as accurate or inaccurate, are referred to as open-ended responses. Chi-square analysis is provided for all items in the data tables.

1. Body Parts

The ladybird beetle, spider, and worm illustrations are included in this section. With all three animal illustrations, it was hypothesized that more students draw body parts correctly in the objective assessment items than would detect inaccuracies in pictures that had body parts misrepresented. The second general hypothesis was that characteristic differences would be found in grade level responses. The third hypothesis addresses the differences in knowledge demonstrated by inspecting pictures and responding to objective tests.

Table 3

Responses to Ladybird Beetle Questions: Illustration Assessment

Illustration Assessment	Percentage by grade			X ²	df
	3	5	8		
	(n=63)	(n= 53)	(n= 61)		
1) states ladybird beetle illustration is incorrect	91.80	85.19	96.83	5.112	2
2) mentions at least two inaccuracies in open-ended responses	50.20	59.66	54.52	.815	2
3) detects incorrect number of legs **	0.00	0.00	4.00	7.289*	2

* Significance at $p \leq .05$

** With two cells having a 0.00 value and degrees of freedom under five, the significance of the result could be called into question.

Table 4
Responses to Ladybird Beetle Questions: Objective Assessment

Objective Assessment	Percentage by Grade			χ^2	df
	3 (n=113)	5 (n=106)	8 (n=113)		
1) draws correct number of legs (question #2)	72.57	59.43	71.05	5.132	2

Table 3 and 4 show the percentage of students who demonstrated correct understanding of body parts on four assessment items related to the ladybird beetle. The results support the hypothesis that more students at all grade levels draw the correct number of legs than detect the incorrect of number of legs in an illustration. Only four students (all 8th graders) in the entire sample mentioned that the ladybird beetle had the wrong number of legs. However, more than 71% of third and eighth graders drew the correct number of legs when answering question #2 on the objective assessment (See Appendix B). Note that a slightly lower percentage of fifth graders drew the correct number of legs compared to other grades. There were five cases of fifth graders who drew 6 pairs of legs (12 legs) or 8 pairs of legs (16 legs) on the legless insect, suggesting that this group may have some confusion about the word "pair."

The hypothesis that more eighth and fifth graders would detect the incorrect number of legs than 3rd graders was not supported by this study. In fact, the results reflect little variation among the grade levels.

In open ended responses, third grade students focused upon inaccuracies such as "bees don't have faces," "bees and lady bugs don't make friends." Older students mentioned that "bugs cannot step on each other backs, or lady bugs don't water" (one student commented, "unless they pee on it!"). Among those students who responded that the illustration was correct ($n = 15$), students stated that "bees and bugs do work together," "bees eat from the flowers, or lady bugs can stand on each other."

The results in Table 5 and 6 support the hypothesis that more students draw the correct number of legs on a spider than detect an inaccuracy in an illustration. The hypothesis that students would demonstrate characteristically different responses was not consistently supported by the results. Chi-square analysis of question #10 in Table 6 does not indicate a significant level of difference

Table 5

Responses to Spider Questions: Illustration Assessment

Illustration Assessment	Percentage by Grade			X ²	df
	3	5	8		
	($n=56$)	($n=55$)	($n=56$)		
1) marks spider illustration as inaccurate	30.91	36.36	51.79	5.445	2
2) states spider has incorrect number of legs	27.27	36.36	42.86	2.996	2

Table 6

Responses to Spider Questions: Objective Assessment

Percentage by Grade					
Objective Assessment	3	5	8	χ^2	df
	(n=113)	(n=102)	(n=113)		
1) draws correct number of legs on spider (#10)	81.00	66.00	88.00	4.687	2
2) draws legs on correct body part (#10a)	11.71	17.00	16.00	1.077	2

although there are large percentage differences between 8th and 5th graders. Ninety percent of all students at each grade level who marked that the spider illustration was inaccurate stated that the spider did not have the correct number of legs. Open-ended responses suggest that some students may have been confused by the three body parts. Table 6 indicates that a small percentage of students at each grade level correctly drew the spiders legs on the correct body part (item #4). Only three 3rd grade students and one 8th grade student stated that a spider does not have three body parts. Even though the illustration contained the word 'spider,' many students may have perceived the picture to be an insect. A few students responded that spiders have 6 legs.

Table 7

Responses to Worm Questions: Illustration Assessment

Illustration Assessment	Percentage by Grade			χ^2	df
	3	5	8		
	(n=54)	(n=55)	(n=55)		
1) marks worm illustration as inaccurate	61.11	56.36	54.55	.511	2
2) indicates that human eyes are inaccurate in open ended response	3.70	21.82	32.73	14.895**	2

** significance at $p < .01$

Table 8

Responses to Worm Questions: Objective Assessment

Objective Assessment	Percentage by grade			χ^2	df
	3	5	8		
	(n=107)	(n=103)	(n=114)		
1) does not draw eyes on worm's body (#7)	54.21	57.28	67.54	4.511	2
2) does not draw extra body parts (#7a)	48.10	39.22	38.60	2.493	2

The results from Tables 7 support the hypothesis that students will not interpret human-like eyes on a worm as scientifically incorrect. While the majority of students at each grade level marked the illustration as incorrect, only 3.7% of third grade students, 21.8% of fifth grade students, and 32.7% of eighth grade students detected the presence of human eyes as incorrect. Chi-square analysis of this item supports the hypothesis that students will demonstrate characteristic differences by grade levels.

Analysis of other open ended responses suggest that third grade students use less scientific evidence to qualify their answers. Typical third grade responses were "worms don't have shirts," (students interpreted the blank spot on the worm as clothes), "worms don't have white spots, and worms do not smile." Some responses suggest that third grade students were confusing the worm with a snake. Common responses with fifth and eighth grade students were "worms do not smile," and "worms do not have faces." Some 8th grade students used questionable logic to justify their accurate responses, such as "earthworm has two heads." With fifth grade students, there appears to be a direct relationship between students who said worms do not smile and those students who did not draw any additional body parts on question #7 in the objective assessment. The inconsistencies at all grade levels between the results on item 2 (Table 7) and item 1 (Table 8) provide evidence that students have confusion and some misconceptions about the body parts of a worm and possibly invertebrates in general. Notice that in the response to question #7a (Table 8), the majority of students added something else to the body of the worm when the correct response was to add nothing to the picture. A few

students drew one eye on the worm and many drew more segments on the worm. The structure of the question and the poor quality of the illustration may have 'tricked' students into thinking that they were supposed to add something to the picture.

2. Interaction: Time and Space Relationship

The student responses analyzed in this section refer to the questions related to the polar bear and the dinosaur illustrations. It was hypothesized for both illustrations that students have misconceptions about human/dinosaur interactions and polar bear/penguin interactions and that there are characteristic grade level differences. It was also hypothesized that responses to objective questions provide different (contrasting) information than that received from responses to the illustrations.

The results from Table 9 generally support the hypothesis that students do not have a scientific understanding of human and dinosaur interactions. A significant exception is found in the results of third grade students who demonstrated more scientific memory or understanding on this topic than the other grades. Although there were significant differences in grade responses, the findings represent a reversed pattern of what was hypothesized. Notice that fifth grade students had the smallest percentage of students who detected inaccuracies in the dinosaur illustration and who mentioned that humans do not live with dinosaurs. Although the majority of students answered questions #1a and #1b (Table 10) correctly, the inconsistency in responses between the two items, especially with third and fifth grade students, suggests that students have

confusion about the interaction between dinosaurs and humans. Examination of students' open-ended responses reveals a variety of misconceptions held by students at all grade levels. As item 2 in Table 9 indicates, not all students gave scientific reasons for marking the illustration as inaccurate.

Table 9

Responses to Dinosaur and Polar Bear Questions: Illustration Assessment

Illustration Assessment	Percentage by grade level			χ^2	df
	3 (n=61)	5 (n=54)	8 (n=63)		
1) marks dinosaur illustration as incorrect	75.41	55.56	57.14	6.235*	2
2) indicates that humans did not live with dinosaurs	52.46	29.63	38.10	6.422*	2
3) marks polar bear illustration as inaccurate	21.82	18.18	15.69	.668	2
4) indicates that penguins/polar bears do not live together	9.09	7.07	6.00	1.650	2
* significance at $p < .05$					

Table 10

Responses to Dinosaur and Polar Bear Questions: Objective Assessment

Objective Assessment	Percentage by Grade			X ²	df
	3 (n=107)	5 (n=102)	8 (n=115)		
1) answers false to #1a	60.75	51.96	71.30	8.627**	2
2) answers false to #1b	85.45	85.05	78.95	2.121	2
3) answers false to #5	60.18	62.26	62.10	.13	2

** significance at $p < .01$

Below are some student responses that reflect misconceptions or misunderstandings about the dinosaur period:

a. Examples of eighth grade responses.

One student stated that "long time ago, man killed animals." "Nobody knows the truth about dinosaurs and the picture is too primitive" were other reasons given for marking the picture as inaccurate. Other responses were "A dinosaur does not stand on two legs" and "dinosaurs are bigger than humans." "He could not kill a dinosaur."

b. Examples of fifth grade responses.

"The leg is in the wrong place." "Caveman would not be carrying a stick"

"Because I saw a movie like this." "Dinosaurs should be bigger than caveman"

(this comment was made several times). "A scientist would not know because he wasn't back at that time." "Men killed other things." "People are scared of

dinosaurs." "The leg is in the wrong place."

c. Examples of third grade responses.

"Man is right shape and so is dinosaur." "A man is smaller." "I have a book that has a picture in it."

The hypotheses related to accepting polar bear/penguin interaction as accurate were supported by the study. There was little evidence of variation of responses at different grade levels. Notice for all grades, fewer than 25% of students marked the illustration as incorrect and of those students, only 3 eighth grade students, 4 fifth grade students, and 5 third grade students in their open-ended responses stated that polars bears and penguins do not live in the same place.

In other open-ended responses among eighth grade students, reasons given for marking the illustration as inaccurate were "penguins are not white," polar bear doesn't stand that way," and "they don't stick together." Eighth grade students more often said that "they live in the same climate" when giving a reason for marking the illustrations as accurate. A few third and fifth grade students responded that they "saw this in a magazine" or they "saw it on T.V."

As with the dinosaur illustration, inconsistencies surface when comparing the results from the two assessments. Notice that 60% of all students marked the statement, "Polar bears eat penguins" as false (Table 10, item 3), compared to the few students who stated that polar bears and penguins do not live together (Table 9). Many students may think that polar bears and penguins live in the same environment but do not eat each other.

3. Interaction: Cause and Effect

In this section, the responses to cloud-related questions is analyzed. It was hypothesized that more students in higher grade levels detect that clouds do not blow air than students in lower grades. It was also hypothesized that the two assessments reveal different results related to the understanding of how movement of wind and clouds is related. The results of the study partially support the hypotheses related to grade level responses and support the hypothesis related to information obtained from two kinds of assessments. More than 90% of students at all grade levels mark the cloud illustration as scientifically inaccurate. Grade level differences surface when open-ended responses are analyzed ($p < .001$ for item 3). Notice that fifth grade students have the lowest percentage for stating that "clouds do not blow air" (Table 11). Fifth and eighth grade students responses reflect the greatest discrepancies when comparing results from the two assessments (Table 11, item 3 and Table 12, item 1) while there is only a 5% and 13% difference, respectively, between 5th and 3rd graders.

4. Biological processes

The items analyzed in this section are from responses to questions related to the fish illustration. It was hypothesized that most students would not mark the fish illustration as scientifically inaccurate. For both kinds of assessments, it was hypothesized that eighth grade responses are significantly different from

Table 11

Responses to Cloud/Wind Questions: Objective Assessment

Percentage by Grade					
Illustration Assessment	3	5	8	χ^2	df
	(n=66)	(n=53)	(n=60)		
1) marked cloud illustration as inaccurate	91.67	90.57	95.31	1.09	2
2) stated that clouds do not have face	76.67	83.02	73.85	1.44	2
3) stated that clouds do not blow air	38.33	33.96	65.15	14.158***	2
4) listed two or more inaccuracies in written answer	28.81	35.85	47.48	1.258	2

*** significance at $p < .001$

Table 12

Responses to Cloud Questions: Objective Assessment

Percentage by Grade					
Objective Assessment	3	5	8	χ^2	df
	(n=113)	(n=107)	(n=111)		
1) #3 false	45.13	58.88	86.49	42.71***	2

*** significance at $p < .001$

fifth and third grade responses. Lastly, it was hypothesized that more students answer false to the question, "A fish exhales air through its mouth," than detect the inaccuracy of a fish blowing bubbles through the mouth. All hypotheses were supported by the results of the study. The percentage was similar between third and fifth grade responses to items 1 and 2 (Table 13), but significantly different from the eighth grade responses. There is a wide discrepancy in understanding of how fish exchange air as demonstrated by the response to question #9, "A fish exhales air through its mouth." It was not determined in a post study whether students had a clear understanding of the word "exhale." Open-ended responses (there were few responses since most students marked the illustration as correct) suggest that the illustration matched what students perceived as a correct depiction of real fish behavior. Some responses by eighth grade students reflected inconsistent scientific understanding such as "Fish use bubbles to catch insects," and "looks like fish you see in pictures." One fifth grader responded, "fish have gills and everything this fish has."

5. Physical Laws

This section analyzes the results from the questions related to the Winnie the Pooh and Roger Rabbit illustrations. It was hypothesized that students show characteristic grade-level differences in their responses to these illustrations and that older students demonstrate more scientific understanding than younger students when investigating illustrations. These hypotheses were not supported by the results of the study. In Table 15, items 2, 3, 5, and 6 refer to whether students used scientific reasons to explain their reason for marking the

Table 13

Responses to Fish Questions: Illustration Assessment

Illustration Assessment	Percentage by Grade			χ^2	df
	3	5	8		
	(n=62)	(n=53)	(n=65)		
1) fish illustration was inaccurate	11.29	11.32	43.08	23.834***	2
2) states fish do not blow bubbles	3.39	5.66	36.51	30.911***	2

*significance at $p < .001$

Table 14

Responses to Fish Questions: Objective Assessment

Objective assessment	Percentage by Grade			χ^2	df
	3	5	8		
	(n=111)	(n=103)	(n=110)))		
1) answers false to #9	56.67	82.52	91.82	40.909***	2

***significance at $p < .001$

Illustration accurate or inaccurate (See Chapter III, Data Analysis, pp.49-50 and Appendix A for more clarification). For the Winnie the Pooh illustration, open ended statements that reflected some understanding that a balloon full of air does not lift up objects or a balloon needs to have the properties of helium to cause a lifting force were marked as a scientific explanation. For the Roger Rabbit illustration, statements that reflected some understanding or awareness about forces that act upon falling objects, i.e., gravity would cause the rabbit to fall as soon as he was no longer supported by the cliff, were marked as a scientific explanation. Notice that eighth grade students do have a higher percentage of scientific responses but Chi-square analysis (Table 15) revealed no significant differences at the .05 level for the Roger Rabbit illustration. Forty-eight percent of eighth grade students still used a cartoon explanation, i.e., "because this is the way a cartoon falls off the cliff," to justify their answers. For item 1 in Table 9, (#6 on the objective assessment) drawing an accurate model was indicated if students drew some kind of line to show that the car would not fall in a path at a right angle to the horizon. The results from this objective assessment item again support the general hypothesis that different kinds of knowledge are demonstrated, depending on the type of assessment used.

Table 15

**Responses to Winnie the Pooh and Roger Rabbit Questions:
Illustration Assessment**

Percentage by grade					
Illustration Assessment	3 (n=60)	5 (n=52)	8 (n=64)	χ^2	df
1) Marked Winnie the Pooh illustration as inaccurate	58.33	44.23	60.94	3.168	2
2) Explained response by stating that character was a cartoon	35.00	34.62	37.50	.129	2
3) scientific reason given to explain inaccuracy	35.09	35.85	49.23	3.223	2
4) Marked Roger Rabbit illustration as inaccurate	40.00	52.73	51.92	2.221	2
5) cartoon rationale given to justify answer (Roger Rabbit)	59.26	40.00	48.00	4.077	2
6) science explanation given to explain inaccuracy	24.07	40.74	44.23	5.369*	2

*significance at $p < .05$

Table 16

**Responses to Winnie the Pooh and Roger Rabbit Questions:
Objective Assessment**

Objective Assessment	Percentage by Grade			χ^2	df
	3	5	8		
	(n=113)	(n= 107)	(n= 110)		
1) draws accurate model of falling car (#6)	57.69	67.96	75.23	7.466*	2

* significance at $p < .05$

Other open-ended responses, mostly from eighth grade students, reflect an inconsistent pattern of understanding of physical laws governing falling objects. "He would have to look down and then fall." "Depends on how fast he is going." "Roger Rabbit would stay in the air."

Some third grade responses reflected scientific understanding such as, "Nobody goes straight out and falls."

Summary of Findings

Table 17 summarizes the results of the study by charting the findings from each illustration and indicating whether the results support or do not support the three general hypotheses stated in chapters I and III. For each hypothesis, a summary statement is given.

Hypothesis A. Fewer than 50% of students in third, fifth, and eighth grades demonstrate an ability to detect scientific inaccuracies in illustrations.

The findings *support* the hypothesis for seven of the nine illustrations in eighth grade, for all illustrations in fifth grade, and for eight of the nine illustrations in third grade.

Hypothesis B. Students in higher grades are more able to detect scientific inaccuracies in illustrations than students in lower grades.

The findings *do not* support the hypothesis for five of the nine illustrations when comparing eighth and third grade students, for six of the illustrations when comparing eighth and fifth grade students, and for seven illustrations when comparing fifth and third grade students.

Hypothesis C. Knowledge demonstrated by inspecting pictures is different from knowledge demonstrated by responding to traditional objective tests.

The findings *support* the hypothesis for seven of the illustrations in eighth grade, for eight of the illustrations in fifth grade, and for six of the illustrations in third grade.

Table 17

Summary of Findings*

Illustration	Hypothesis A			Hypothesis B			Hypothesis C		
	8	5	3	8 & 3	8 & 5	5 & 3	8	5	3
1) Lady bird beetle	Y	Y	Y	N	N	N	Y	Y	Y
2) Spider	Y	Y	Y	N	Y	N	Y	Y	Y
3) Worm	Y	Y	Y	Y	N	Y	Y	Y	Y
4) Dinosaur	Y	Y	N	N	N	N	Y	Y	N
5) Polar Bear	Y	Y	Y	N	N	N	Y	Y	Y
6) Cloud	N	Y	Y	Y	Y	N	N	Y	N
7) Fish	Y	Y	Y	Y	Y	N	Y	Y	Y
8) Winnie the Pooh	N	Y	Y	I	I	I	N	N	N
9) Roger Rabbit	Y	Y	Y	P	N	P	Y	Y	Y

**Key to Responses*

Y=Hypotheses supported

I = Inconclusive evidence

N= Hypotheses not supported

P= Partial Evidence to support hypotheses
(support for some items but not for others)

CHAPTER V

SUMMARY AND DISCUSSION

Overview of Study

The primary purpose of this study was to determine whether students can detect scientific inaccuracies in illustrations. In addition, students' understandings of the inaccuracies were investigated by analyzing open-ended explanations of their responses to the illustrations and by comparing the responses to the illustrations to an objective test on related content knowledge.

Third, fifth, and eighth grade students from the Monterey Peninsula Unified School District participated in the study, which involved responding to a set of illustrations typically used for motivational purposes within science instructional materials. Each illustration contained at least one scientific inaccuracy. Students' identifications and descriptions of errors in the set of illustrations were compared to responses given on an objective assessment that measured the same knowledge. The results addressed four research questions that considered (1) student abilities to detect inaccuracies; (2) differences among third, fifth, and eighth grade responses to both assessments; (3) key characteristics and patterns of understanding revealed by student responses; and (4) differences in the patterns of understandings revealed by the responses to the two assessments. For most illustrations, at all grade levels, students correctly indicated that an inaccuracy existed but did not identify the associated scientific fact or concept. Responses to open-ended items differed from

responses to corresponding items in the multiple choice format, e.g., students drew correct number of legs on a ladybird beetle (objective assessment) but could not identify the incorrect number of legs on the beetle in the illustration. Expected differences between grade levels were not demonstrated consistently. The following generalizations can be made from the findings: (1) students may indicate that an illustration is incorrect but are not able to identify the associated scientific error; (2) student abilities to detect scientific inaccuracies in illustrations does not necessarily correspond to grade level; (3) alternate conceptions surface when students are asked to explain scientific inaccuracies in illustrations; and (4) knowledge reflected by responses to the set of illustrations is not the same as knowledge reflected by responses to the objective test.

The results of the study suggest that (1) teachers must not assume that students can detect inaccuracies in motivational illustrations, and (2) teachers can learn about student understandings of science concepts by providing opportunities for students to interpret and discuss scientific inaccuracies that occur in a variety of visual media.

Discussion of Student Responses

Patterns of responses to illustrations were made apparent by clustering illustrations based on similar attributes. For purposes of discussion, the illustrations have been grouped based on whether detecting a specific inaccuracy required factual recall, conceptual understanding, or higher levels of thinking, such as recognizing relationships. The illustrations were divided into

groups as shown in Table 18. The results from each category are discussed, and are followed by a presentation of four generalizations that precipitate from several or all of the categories.

Table 18

Illustration Categories

Categories	Illustrations	Thinking Process Required
Body parts	spider with six legs worm with eyes and lady bug with four legs	factual recall of anatomical characteristics
Interactions: Time and Place	Polar Bear stalking penguins, dinosaur hunted by caveman	understanding of geologic time, identify incorrect interactions between animals
Interaction: Cause and Effect	Clouds with face	understanding of what is alive/not alive, understanding of how wind is made
Biological Process	Fish blowing bubbles	acceptance of concept of gas in liquid solution, understanding of fish anatomy and function
Physical Laws	Winnie the Pooh being lifted by balloon, Roger Rabbit running in mid air	Understanding of buoyancy, path of falling objects, momentum and force of gravity, distinguishing between cartoons and "reality"

1. Body Parts

Students' answers to the objective assessment items indicated knowledge of body parts, although the students failed to detect inaccuracies in the

illustrations. Students' inabilities to focus on, or independently recall, the "standard knowledge," such as ladybird beetles have six legs, spiders have eight legs, and worms do not have eyes, contrasted with their "correct responses" to the corresponding items in the objective assessment. This pattern supports the notion that fact-oriented knowledge, learned by rote, has little transference when students are given a more problem-oriented, open-ended question (Gardner, 1991). From a constructivist perspective, if students have not been provided the opportunities to explore, investigate, ask questions, and construct their own understandings about the characteristics of animals, "real understanding" will not be achieved and will not be available to use in new situations. Typically, students are taught characteristics of animals with anatomically correct examples. Can they independently recall these correct models to help analyze an illustration for inaccuracies without having had some practice with what's-wrong-with-this-picture exercises?

In this study, students had to spontaneously apply their knowledge when asked the question, "Would a scientist say this picture is correct?" and "Explain your answer." Although the items in the body part category did not require problem solving skills, the findings do suggest that students were not able to bring up factual knowledge when asked to respond to more open-ended questions.

In the case of the ladybird beetle, an illustration with many components, the overwhelming lack of recognition by students at all grade levels that the ladybird beetle only had four legs relates to other studies that document that students have difficulty discerning errors in illustrations that have several items or they will focus upon features in the foreground of a picture and pay less

attention to other parts of the illustration (Reid,1990). In addition, the types of responses given by students is affected by the amount of experience students have had in analyzing illustrations and looking for inaccuracies in pictures. It is likely that if students in this study had previous experiences in analyzing various forms of visual images, the discrepancies between responses given on the two assessments may not have been so extreme.

The frequency of correct responses to the objective assessment items may reflect the phenomenon of "taking cues from the test." For example, the sample question given as part of the instructions for taking the objective assessment was (true or false) "An insect has six legs." Students were alerted to a science fact that directly related to answering a subsequent question requiring them to draw legs on the ladybird beetle. The wording in the questions themselves posed in the objective test may have served as memory prompts and may account for the majority of students at all grade levels responding correctly to the objective items on body parts (Chapter IV, Tables 4,6,8).

In contrast to the ladybird beetle illustrations, a far greater number of students stated that the spider had an incorrect number of legs, although at no grade level did a majority of students detect this inaccuracy. The spider illustration resembles a picture that appear in *AIMS*, a math and science curriculum used nationally for the elementary grades, and its poor quality may have contributed to students' confusion (see Chapter III, p. 39). Inspecting the spider illustration did not involve discriminating within a field containing many details as for the ladybird beetle picture, which may partially explain why a larger percentage of students detected the spider drawing as inaccurate.

Three students who marked the spider illustration as *correct*, justified their answer by stating, "A spider has six legs." Even though the word "spider" is used in the illustration, the picture portrays the spider as being insect-like with three body parts instead of two. This may suggest that either the student's knowledge of spider's body parts is "shaky," e.g., a spider really is an insect, or that the visual cue, depicting the spider as an insect, had more impact on the student giving an answer than the written cue of "spider."

Student responses to the worm illustration indicate that a significant percentage of third grade students are unaware that worms do not have eyes or believe that worms have eyes, a finding that has been confirmed by this researcher's informal observations of third grade students as they carry out earthworm studies. It is typical to observe students, during lab activities, looking for any evidence, even specks of dirt on the worm, to interpret as eyes, in order to confirm their preconceptions that worms have eyes. This is consistent with other findings in the literature that document students' determination to hold onto their alternate conceptions (Watson & Konicek, 1990). A higher percentage of fifth and eighth grade students detected the inaccuracy, yet almost 40% of these students drew inappropriate body parts on the worm in item #7 of the objective test. Inclusion of interview techniques, such as those used by Bell (1981, 1985), Gilbert, Watts, and Osborne (1985), Posner and Gertzog (1982), and Driver and Oldham (1986) would have helped clarify knowledge of student understanding regarding worm anatomy and other science concepts addressed in this study.

The quality of the rendition of the worm and spider may have confused a few students. Four students referred to the worm as a snake and, as stated

earlier, three students interpreted the spider as an insect. Whether this was a result of the precision of the drawing or an indication of the students' animal classification schema is not clear.

The confusion demonstrated by the responses to the illustrations of the beetle, spider, and worm may reflect students' uncertainty about the nature of invertebrates. Studies have documented that many students do not regard invertebrates such as spiders and worms as animals (Bell, 1981; Stephens, 1985; Trowbridge & Mintzes, 1988). Studies that examine how inaccuracies in visual images of invertebrates affect understanding of this major group of animals merit further consideration.

2. Interaction: Time and Space

Two illustrations addressed an awareness of living things coexisting in time and space. In the case of the man chasing a dinosaur, a majority of fifth and eighth grade students did not detect the inaccuracy of interaction between humans and dinosaurs, which were extinct before humans evolved. Answers to the related items in the objective assessment appeared inconsistent with written responses to the illustration (Tables 9,10). That is, on the objective test, students demonstrated knowledge that humans and dinosaurs did not coexist, but did not recognize that incongruency in the illustration.

Students have a difficult time understanding the concept of time, especially as it relates to geologic time. The results of this study indicate that students hold several misconceptions about the relationship between humans and dinosaurs. These are documented in the open ended responses in Chapter IV. Students often dismissed scientific processes with comments such as, "nobody knows the

truth about dinosaurs" or a "scientist would not know because he wasn't back at that time," and opted for reliance upon visual experience to explain their choices such as, "I saw a movie like this" or "I have a book that has a picture in it." Since many of these statements were made by eighth grade students, this finding is consistent with research that suggests that visual images stored in memory impact a child's conceptions of phenomena that are not directly experienced, far more strongly than words stored in memory (Peeck, 1987; Blystone & Dettling, 1990). In addition, the student comments do convey some understanding that much of scientific theory is based upon indirect observation.

Several researchers have commented on the tendency for students to distinguish between school science and real science (Schollum & Osborne, 1985; Vosniadou, 1988). In this study, 20% more third grade students than fifth grade students and 18% more third grade students than eighth grade students indicated that the dinosaur/ caveman illustration was scientifically inaccurate. It is not surprising that third grade students may reflect a greater knowledge of dinosaurs because there is so much involvement, both formally and informally, by primary children with the subject of dinosaurs. However, this understanding may reflect a more recently memorized fact rather than a true scientific understanding of organisms occupying specific windows of geologic time. As the fascination and interest in dinosaurs wanes, students may fall back upon prior schemata about human-dinosaur interaction, namely that humans did live at the same time as dinosaurs. Students may adopt or recite teachers' ideas to please the teacher but as time passes, facts are easily forgotten, and former understandings prevail, or are altered by contradictory images in the popular

media. The literature documents that these factors influence how students learn about science.

For the two illustrations that deal with the interaction of time and place, specific developmental patterns were not found. The contradictory understandings demonstrated by fifth and eighth grade students' responses to items #1a and #1b in the objective assessment parallel similar findings by Schollum and Osborne (1985) that reveal that students are not concerned about inconsistency of thought.

Both illustrations in this section depict a relationship or interaction between the characters in the pictures. Studies cited in Chapter II address how children interpret pictures. Developmentally, students before the age of eleven do not concentrate on themes that may be implied in a picture (Peeck, 1987). Polar bears, penguins, and dinosaurs are not in the realm of real experience for most students. Instead of deciphering a correct or incorrect interaction between the characters, students focused on very specific items such as, "a dinosaur does not stand on two legs, or "caveman would not be carrying a stick."

When the phenomena being studied exists outside the learner's experience, as is the case of penguins and polar bears, students often cited " I saw it in a magazine, or I saw it in the movies." Fewer than 10% of the students indicated that penguins and polar bears did not live together. We do not know from the findings of this study if the 90% of students who marked the polar bear illustration as accurate had received classroom instruction at any time about polar bears. The findings suggest that visual images experienced in informal settings play a more significant role in student understanding than any scientifically correct information received in the classroom.

3. Interaction: Cause and Effect

Ninety percent of all students marked the cloud illustration as inaccurate while fewer than forty percent of eighth and fifth grade students indicated that clouds do not blow air. There were distinct developmental patterns that surfaced when comparing eighth and third grade responses to the cloud illustration, especially pertaining to tendencies to mention that clouds do not blow air (Table 11). It is noteworthy that several open-ended responses reflect the same kind of understandings found by Piaget in his work on animism. If there is an action associated with an object, students attribute a living quality to that object. It is consistent with other developmental research that third grade students would attribute living characteristics to a cloud (Bell, 1981).

The wording of item #3 (Table 12) and the assessment limitations of true-false questions to provide insight into student understanding make it difficult to generalize about the results. The response to "wind comes from clouds" does not provide information about student conceptions of how wind or clouds are formed. Answering false to this question may reflect a student guess.

Several fifth grade students stated that "clouds don't have faces but they blow wind or they just blow." Constructivists would argue that unless these students were confronted about their misconceptions at some point, through their formal schooling or through contradictory experience, they will hold onto prior conceptions. Useful information could be ascertained about fifth grade conceptions by demonstrating cloud formation and interviewing students about their understanding. The interaction of hot and cold air does produce condensation, clouds, and wind. Do students confuse the making of

condensation with the making of wind? A level of abstraction and formal thinking is required to separate these two phenomena and not rely upon intuition. Only eighth grade students' responses demonstrated scientific reasoning such as "clouds are made up of water vapor and not wind."

4. Biological Processes

Twelve percent of third and fifth grade students and almost fifty percent of eighth grade students marked the fish illustration as inaccurate. A much smaller percentage of students at each grade level indicated that fish do not blow bubbles. Analysis of the interpretation of the fish illustration becomes problematical because most third and fifth grade students marked the illustration as accurate, and consequently, did not write an explanation for their answer. Third and fifth grade students, compared to eighth grade students, are more likely to encounter books that show fish blowing bubbles or display motivational illustrations that contain scientific inaccuracies. It is beyond the scope of this study to determine how the visual images encountered in a student's past affect current understanding, but there is evidence that students relied upon those visual experiences to provide rationales for their answers.

The responses to the cloud and fish illustrations are the only items where significant developmental patterns (Tables 11-12, 13-14) were demonstrated between eighth and fifth, and eighth and third grade students. It cannot be extrapolated from the data whether eighth grade students had experienced considerable hands-on activities related to fish investigations. As in the case where students observed worms, this researcher's informal observations of students examining goldfish indicates that students will look for evidence to

support their prior conceptions that fish blow bubbles. If bubbles appeared anywhere in the water, students responded with a "See, I told you the fish blow bubbles." Watson and Konicek (1990) documented similar behavior with fourth grade students who insisted that "warm clothes" are hotter themselves than "cool" clothes and proceeded to misinterpret temperature data from their own experiments to verify their belief.

The statement in question #9, "A fish exhales through its mouth," may not have been understood by younger students. If so, student answers may result from guessing, rather than an awareness about whether fish breathe air through their mouths.

5. Physical Laws

One intent of this study was to determine student abilities to discriminate between accurate and inaccurate depictions of scientific phenomena in a cartoon. In the Winnie the Pooh illustration, the bear is being carried upwards by a balloon. The Roger Rabbit illustration shows the rabbit running from a cliff and continuing to run in midair before falling straight down. Fifty-eight percent of third grade students, 44% of fifth grade students, and 60% of eighth grade students marked the Winnie the Pooh illustration as inaccurate. In terms of the Roger Rabbit illustration, no distinct patterns of responses between the grade levels were indicated.

The findings from the two illustrations provide ambiguous results about student understanding of forces that act upon objects. Of those students who marked the two illustrations as inaccurate, 67% of third grade students, 77% of fifth grade students, and 82% of eighth grade students used scientific

explanations to explain their answers. This suggests that these students demonstrated some abilities to discriminate between "cartoon reality" and "scientific reality." For those students who marked the illustrations as accurate, what type of understanding is demonstrated? The question, "Would a scientist say this is accurate," was not a valid question for many students. Rather, they applied a "cartoon scheme" when interpreting the two illustrations, i.e., cartoons do not have anything to do with reality. As one student noted, from the perspective of a cartoon scheme, "Roger Rabbit always looks down before he falls." In an interview situation, that same student could be asked to clarify his response and possibly would reflect a greater scientific understanding that objects in such motion will fall in a curved pathway rather than in a perpendicular fashion.

Generalizations

Certain patterns of responses seemed consistent when the findings of this study were analyzed. For purposes of this study these consistent patterns will be called generalizations. Four generalizations are discussed here that relate to the research questions stated in Chapter I and III.

1. The following generalization is made in response to the research question, Can students detect scientific inaccuracies? **Students may indicate that an illustration is incorrect but are not able to identify the associated scientific error.**

In seven of nine cases, students marked an illustration as incorrect but were not able to identify the associated scientific error (spider, worm, ladybird beetle, cloud, dinosaur, polar bear/penguin, fish, and Roger Rabbit). The schemata and level of knowledge that students bring to the learning situation clearly affects their ability to detect inaccuracies. From a student's perspective, penguins and polar bears both live in a cold weather climate. In that schema, it is consistent to view a picture of a polar bear and penguin together as correct. Factual knowledge about habitats indigenous to the penguin and polar bear represent a more sophisticated awareness. As indicated in the previous discussion, the findings do not indicate whether the 90% of students who marked the polar bear illustration as accurate had received any classroom instruction about polar bears. Would students' abilities to detect inaccuracies increase if they had a more extensive knowledge base?

John Gardner (1991) provides some perspective in considering this question of whether students can use knowledge in different contexts. Gardner views on real understanding are summarized in Chapter II. As opposed to the "intuitive learner" (the unschooled mind) or the "scholastic learner" (traditional student), the "disciplinary expert" (skilled person) can apply his knowledge in new situations that may not coincide with predictable encounters in a controlled school setting. He argues that rote, repetitive learning does not promote real understanding because the nature of that mode of learning restricts the development of problem solving skills. Student knowledge of spiders, insects, and dinosaurs may not extend beyond the understanding reflected in "repetitive learning and short answers." If factual knowledge is not purposeful to the learner, then detecting inaccuracies in a spider illustration may seem

meaningless, and factual knowledge is not transferred to a problem solving situation. Indeed, even the fascination with a subject such as dinosaurs does not promote "genuine understanding" unless there is an environment in which children are testing and exploring their own ideas with other points of view, including related scientific viewpoints. Otherwise, as evidenced by this study, we observe the phenomenon of eighth grade students demonstrating no more genuine understanding of human/dinosaur interaction than third grade students.

2. The following generalization is made in response to the research question, Are there significant differences between responses given by third, fifth, and eighth grade students on the two kinds of assessment? **Students' abilities to detect scientific inaccuracies in illustrations do not necessarily correspond to grade level.**

Table 17 (Summary of Findings) in Chapter IV indicates that the general hypothesis, "Students in higher grades are more able to detect scientific inaccuracies in illustrations than students in lower grades," was not supported by the findings. With the body parts and interaction illustrations, fifth grade students did not demonstrate any higher degree of detecting scientific inaccuracies than third grade students. Fifth grade students still conceptualize at a concrete level of operations and rely upon sense impressions to provide understanding of the natural world. Their open ended responses to the cloud and dinosaur illustrations revealed a lack of scientific reasoning.

Students can memorize facts such as fish do not blow air, dinosaurs did not live with humans, and worms do not have eyes, but these facts do not

represent a conceptual understanding of fish anatomy, geological time, or invertebrate structures. The literature supports the notion that visual images have a impact upon student learning. If a student's knowledge base is "shaky" (learned in a rote manner), their real understanding may be easily influenced by visual images, images they encounter several times a day, that reflect misconceptions or incorrect information. Conversely, if a student possesses a conceptual understanding of a scientific phenomenon, incorrect visual images are less likely to influence the learner.

Data have not been analyzed to determine if significant differences exist between fifth grade students at site A, B, and C. Fifth grade students at site A do reflect a higher socio-economic status. It would be valuable to determine if a causal relationship exists between socio-economic status and developmental differences in scientific understanding. In addition, it is recognized that this study sampled only 3rd through 8th grade students.

3. The following generalization is made in response to the research question, What are some key characteristics and patterns of understanding revealed by the responses of third, fifth, and eighth grade students asked to identify scientific inaccuracies in illustrations? **Evidence of alternate conceptions surface when students are asked to detect scientific inaccuracies.**

Students' responses to the dinosaur, worm, fish, and cloud illustrations indicate the presence of alternative conceptions. Open ended responses reveal that students rely upon memory of stored visual images to validate their conceptions about fish breathing, worms having eyes, and clouds blowing air. This tendency seems to increase when the phenomenon being studied exists

outside the learner's experience, as in the case of penguins/polar bears and dinosaurs. Students often cited " I saw it in a magazine, or I saw it in the movies." Eighth grader students in this study seemed to distinguish between "school science" and "real science" by dismissing the role of scientists, e.g., "scientists were not around the time of the dinosaurs." These findings parallels other studies which have documented children's tendencies, not exclusive to children by any means, to misinterpret information to correspond to their existing schemata (Osborne & Wittrock, 1983). It appears in most cases that students in this study have not been confronted or challenged about their alternate conceptions. If so, past classroom instructions in corresponding content areas will have had minimal impact on changing the preconceptions they bring into the classroom.

4. The following generalization is made in response to the research question, Are patterns of understanding revealed by student responses to illustrations different from those revealed by responses to an objective test that assess the same content knowledge? **Knowledge reflected by responses to objective tests is not the same as knowledge reflected by responses to open ended questions.**

Two kinds of assessment were used. The objective test, a traditional instrument, provided a profile of knowledge triggered by verbal cues, consistent with the predominantly verbal instruction that exists in schools. Open-ended responses to the illustrations, however, revealed a different kind of knowledge profile, one that revealed different facets of thinking. As indicated earlier, in seven of nine cases, factual knowledge reflected in responses to objective

assessment items did not correspond with students' abilities to identify associated scientific inaccuracies in the illustration. Cognitive scientists who address the issues of different representations of knowledge can provide some perspective.

Detecting inaccuracies in an illustration involves some of the attributes of spatial intelligence, such as using mental imagery, recognizing instances of the same element and transforming visual knowledge into other forms of knowledge. There is conclusive evidence that discrepancies exist between knowing something, expressing that body of knowledge, and representing that knowledge in an illustrative or pictorial format (Gardner, 1983). Findings of this study suggest that *interpreting* knowledge in a picture format, e.g., detecting inaccuracies, is a different skill and process than detecting and interpreting errors in a print format. Just as drawing a picture is different than writing, detecting a scientific error in a picture is different from detecting an error in print. Just as many students require experience for developing spatial intelligence, students need varied experiences with the process of interpreting visual images in order to do so spontaneously.

Objective tests, such as the one designed for this study, often measure students' abilities to recall factual knowledge. The illustration assessment required students to reflect upon their answers and give written responses. In the process of reflecting upon why an illustration is inaccurate, incomplete understandings surface that are not apparent when students are only asked to recall information.

Additional Insights

Developing appropriate test items that accurately measure knowledge of content understanding can be a difficult task. For example, responses to the objective test items #1a, #1b, #3, and #5 (dinosaur, wind/cloud, and polar bear, respectively) in this study present an incomplete picture about student understanding. This aspect of the study serves as a reminder that teachers need to be cautious and selective about the wording of any test item.

Item design affects the kinds of generalizations that can be inferred from student responses. If a student answered false to the statement "Caveman hunted dinosaurs," a teacher or researcher cannot deduce that the student thinks that caveman and dinosaurs did not live together. Similarly, if a student answered false to item #5, "A polar bear eats penguins for food," this does not demonstrate that a student understands that polar bears and penguins do not live in the same area. Unless there is precise information that can be isolated by using other techniques such as interviews, there are limits to the understandings about student learnings a researcher or teacher can derive from analysis of responses to objective tests.

Tables 3 and 11 contain data referring to how many inaccuracies students noted in their written responses. Their "unwillingness" to look for more than one inaccuracy (or more than one answer) may reflect their own conditioning to answering questions rather than an indication of limits of actual knowledge.

The initial instructions (Appendix C) may have influenced student performance on the illustration booklet. The sample pictures of the insect and

the dog led students to think that the only purpose of the activities was to look for incorrect body parts.

Implications for the Classroom

Visual images have a profound effect upon learning. Visual images stay in memory far longer than verbal input (Blystone & Dettling, 1990). The responses to the open-ended questions in this study included references by students to pictorial and visual images to justify responses that are incorrect. In addition, motivational illustrations often are simple line drawings or in cartoon format and are subject to variation in interpretation, dependent upon knowledge background. Such illustrations, although simple in design, may represent complex ideas. The diversity among the explanations given by students for errors in specific illustrations indicate variation in understanding the associated science error. The findings support the notion that visual aids should be selected with care and with the awareness that visual images can reinforce or maintain alternate conceptions.

Three recommendations for classroom practice that are suggested by the findings:

- 1. Educators should not assume that students can detect inaccuracies in illustrations. Students should have many opportunities to detect and discuss scientific inaccuracies in a variety of visual media.** Motivational illustrations that contain scientific inaccuracies are used within instructional materials. As shown in this study, students were not able to identify the scientific errors in these illustrations. The

task of detecting scientific inaccuracies may require the learning skills of a student who is a "disciplinary expert" (Gardner, 1991). Motivational illustrations should be scrutinized as closely as instructional illustrations when reviewing instructional materials

2. Assessments that encourage open-ended responses can increase teacher knowledge about student thinking. Open-ended assessments provide the opportunity for a more realistic and complete analysis of a students' conceptual understanding. As indicated in this study, when students are given the opportunity to reflect and explain their responses to illustrations, alternate conceptions surface. Often, this facet of student thinking is not "uncovered" when instruction is based solely on verbal cues or assessment that asks for recall of information. As mentioned in Chapter II, there are several techniques available to the classroom teacher, such as interview-about-instances and interview-about-events techniques, that uncover student ideas and expose alternate conceptions which may interfere with acceptance of scientific ideas.

3. Interpreting illustrations and other visual media should be an on-going process in science. In this study, students' responses to the illustrations often revealed a dependency upon visual images in memory. Visual images, whether present or stored in memory, influence how students think in specific learning situations. Educators should examine, along with their students, how to interpret and derive meaning from images that are associated with science concepts. This process could involve discussing conflicting ideas,

comparing alternate views with a student's views and then clarifying their understanding as a outcome of the activity. By creating a learning environment that encourages students to reflect on images encountered in everyday situations, students get practice in applying knowledge in different contexts. It is through such practice that students can move toward the goal of becoming a "skilled" learner and who can apply knowledge, spontaneously, in situations beyond those found in a controlled school setting.

Implications for Further Research

Opportunities for extended research include (1) carrying out further analysis of the data from this study, (2) use of interviewing for clarification of student explanations, and (3) investigating student abilities to detect inaccuracies in other visual media.

Analysis of findings was limited to response patterns for the whole sample. Valuable insight about student understanding could be gained by analyzing the data to determine correlations between different assessment items. For example, how many students who detected that worms have eyes also indicated that fish do not blow bubbles? A study that incorporates interval data would facilitate that type of analysis.

Follow up studies that incorporate interview techniques could probe more deeply into student thinking about the illustrations used in this study. In particular, these interviews could clarify student responses to the human/dinosaur illustrations, particularly, eighth grade students' conceptions about geologic time.

Additional studies are needed to look at students' abilities to detect scientific inaccuracies in all forms of visual media. Interesting questions to ask could include: Do television shows, such as the *The Dinosaurs*, exert significant influence on scientific understanding of specific concepts? Do the popular media, television and comics, precipitate change of understanding toward the error side? Do the misconceptions rampant in a program like the *Flintstones* seriously interfere with the acceptance of a scientific viewpoint? How much do the subtle and not so subtle messages in pop culture programs influence acceptance of scientific inaccuracies?

Experimental studies that explore student abilities to detect scientific inaccuracy in visual media before and after instruction could increase teacher knowledge about the role of classroom instruction in changing or maintaining students' preconceptions.

This study did not try to establish a relationship between the responses to the illustrations, conceptual understanding and cognitive stages of development. Such a line of investigation would be interesting to pursue.

Conclusion

This study investigated the ability of 3rd, 5th, and 8th grade students to detect scientific inaccuracies in selected illustrations that typically are used for motivational purposes within instructional materials. Although previous studies have shown that the use of illustrations assists the learner in retention of textual information, there has been little research that examines how students interpret

visual images, and specifically, whether students are aware of errors in illustrations used in informal contexts.

In addition, this study compared students' identifications and descriptions of errors in the illustrations to knowledge reflected by answering questions on an objective test that measured similar content, and sought to identify patterns within the student responses.

Results of this study demonstrated that: (1) although students marked illustrations as inaccurate, in most cases they were unable to identify the associated scientific error; (2) student abilities to detect scientific inaccuracies do not necessarily correspond to grade level; (3) the open ended explanations for responses given to the illustrations revealed facets of student thinking (alternate conceptions) that were not apparent or identifiable by examining the responses to the objective assessment; and (4) knowledge reflected by objective tests is not the same as knowledge reflected by responses to open-ended questions.

The findings from this study imply that teachers need to exercise caution in their selection and use of illustrations in teaching science. Illustrations with scientific inaccuracies can be used by teachers to explore students' alternate understandings of science concepts and to provide practice for students in the process of interpreting and analyzing visual images. In a constructivist environment, discussion of inaccuracies in illustrations can help students clarify their understanding of science concepts in a variety of contexts.

This investigation complements studies on the effects of visual images on learning and the effects of student preconceptions or alternate conceptions on interpretation of instructional materials.

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APPENDIX

THE WHAT WOULD A SCIENTIST SAY BOOKLET(A)

STUDENT NUMBER _____

SCHOOOL - MARINA VISTA

GRADE - FIFTH

SAMPLE ILLUSTRATION

Would a scientist say this is a correct picture
of an insect?

Yes _____ No _____

If your answer is no, mark a circle on the
part of the picture that is not correct.

Explain your answer.

Would a scientist say that this picture of
lady bugs and a bee is correct?

Yes _____ No _____

If your answer is no, mark a circle on the
part of the picture that is not correct.

Explain your answer.

Would a scientist say that this is a correct picture?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

Would a scientist say that this is a correct picture of a fish?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

Would a scientist say that this is a correct picture of a cloud?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

Would a scientist say that Winnie the Pooh could do this?

Yes _____ No _____

If your answer is no, mark a circle on the part(s) of the picture that is (are) not correct.

Explain your answer.

THE WHAT WOULD A SCIENTIST SAY BOOKLET(B)

STUDENT NUMBER . . .

SCHOOOL - MARINA VISTA

GRADE - FIFTH

SAMPLE ILLUSTRATION

Would a scientist say this is a correct picture of an insect?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

Would a scientist say that this is a correct picture of a spider?

Yea _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

spider

Would a scientist say that this picture of a polar bear and penguins is correct?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

Would a scientist say that this is a correct picture of a worm?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer. —

Would a scientist say this is a correct picture of what happens to a seed after the plant begins to grow?

Yes _____ No _____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

Would a scientist say that this is the way
Roger Rabbit would fall from a cliff?

Yes _____ No _____

If your answer is no, mark a circle on the
part of the picture that is not correct.

Explain your answer.

FOLLOW UP ASSESSMENT ✖

STUDENT NUMBER _____

DIRECTIONS:

SAMPLE : An insect has six legs.

Circle TRUE OF FALSE

1) Cavemen hunted dinosaurs

Circle TRUE or FALSE

1b) Cavemen helped cause the dinosaurs to become extinct.

Circle TRUE or FALSE

2)

Here is a picture of a lady bug's body. Draw where the legs go on its body.

3) Wind comes from clouds.

Circle TRUE OR FALSE

✖ Note: Items #8 and #12 were not used in the data analysis for this study. Data collected about Item #11 was not considered because the corresponding illustration in the first assessment was dismissed because of its confounding design.

4)

This is a balloon tied to metal screw.

This is a balloon tied to a stuffed animal.

This is a balloon tied to a truck.

Circle the statement that is TRUE.

- A. The balloon can lift up the metal screw.
- B. The balloon can lift up the stuffed animal.
- C. The balloon can lift up the truck.
- D. The balloon can lift up the metal screw and the stuffed animal.
- E. The balloon cannot lift up any of the objects.

5. A polar bear eats penguins for food.

Circle TRUE or FALSE

Draw a line to show how the car would go off the cliff.

7)

This is a worm. Draw any missing body parts on the worm.

.....

8. The sun revolves around the earth.

Circle TRUE or FALSE

.....

9. A fish exhales air through its mouth.

Circle TRUE or FALSE

.....

10.

Here is a picture of a spider's body. Draw where the spider's legs would go on its body.

.....

11)

Picture #1 shows a bean seed in the ground.

Picture #2

Picture #3 shows the bean plant after it has grown for a while.

IN PICTURE #2, SHOW HOW THE BEAN PLANT WOULD GROW BEFORE IT REACHES THE STAGE OF GROWTH IN PICTURE #3. MAKE SURE YOU SHOW WHAT HAPPENS TO THE BEAN SEED.

=====

12. Water is a solid substance.

Circle TRUE or FALSE

=====

VIDEOTAPE SUMMARY

OPENING DIALOGUE

Hello, I am Don Blagsvedt, a elementary science teacher in the MPUSD. Your teacher has agreed to help me in this special study today. All of you have looked at hundreds of pictures in your life, including science related books. Sometimes these pictures that are in science related books are accurate, sometimes they are not. But what is really important is not so much whether the pictures are correct, but how you as a student and a learner interpret those pictures.

Today you are going to make an important contribution to a research study. Your job is very important because the results of this study should help teachers and illustrators (those people that make illustrations in science books) do a better job of using pictures and illustrations in science classrooms.

Your first task is to imagine yourself as a scientist. Remember that an important job of a scientist is to look for accuracy . You are going to be given a booklet of five pictures that are similar to pictures found in science related materials used in the schools.

Here is an example of the kind of picture you will find in your illustration booklet. For each picture, there will be the following question:

Would a scientist say this is a correct picture of an _____?

Yes_____ NO_____

If your answer is no, mark a circle on the part of the picture that is not correct.

Explain your answer.

You may mark more than one thing wrong. If so, please explain why you marked a circle for every case.]

You are encouraged to explain any yes answers that you may give.

Remember that there are no right or wrong answers . Your teacher and I are interested in your own explanations. Your teacher may now pass out the booklets.

TEACHER DIRECTIONS FOR CONDUCTING STUDY

**** Before beginning activity, make sure you have assigned numbers to each child. Researcher will assign the range of numbers for each class. (i.e., #25-50, # 30-60, ect.)***

- 1) Explain to students that today they are doing an activity where they will be thinking like scientists and at the same time be helping teachers learn more about how students think .
- 2) Let's listen to the video and find out more. For third grade classes, pass out booklets before video and have them write their responses to the sample illustration.
- 3) After the video (5 minutes long), pass out booklets and tell students their number. This number should be immediately written down on each page of the illustration sheet. Teacher needs to keep record of number assignments for researcher.
- 4) Insist on individual work and encourage students to explain their answers. There are no right or wrong answers in this activity.
- 5) Students turn over booklets when they are done and then collected by teacher.
- 6) Please keep the results for each class seperated from each other.

A big thank you for all of your help!

Don Blagsvedt