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Everyday visualization: An inquiry into fourth and fifth-grade classroom practices

Thakkar, Umesh, Ph.D.
The Ohio State University, 1993
EVERYDAY VISUALIZATION:
AN INQUIRY INTO FOURTH AND FIFTH GRADE
CLASSROOM PRACTICES

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Doctor Degree of Philosophy in the Graduate
School of the Ohio State University

By

Umesh Thakkar, B.S., M.A.

Ohio State University
1993

Dissertation Committee:
Dr. John C. Belland
Dr. Suzanne K. Damarin
Dr. William D. Taylor

Approved by

Advisor
College of Education
Department of Educational Policy
and Leadership
Instructional Design and Technology
In memory of my younger sister Rita
and
with gratitude to the Ohio State University community
ACKNOWLEDGEMENTS

'What do I have that I have not received?' I would then like to acknowledge the advice and support of my committee members: Professors John C. Belland, Suzanne K. Damarin, and William D. Taylor. My committee members maintained a teacher-friend relationship which nurtured me in the field of instructional design and technology.

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VITA

1988 ......................................................... B.S.,
Computer and
Information Science,
Ohio State University

1989-91 ..................................................... Teaching Assistant,
Academic Computing
Services,
Ohio State University

1990 ......................................................... M.A.,
Instructional Design
and Technology,
Ohio State University

1990 (Autumn) ........................................... Teaching Assistant,
Instructional Design
and Technology,
Ohio State University

1992 ............................................................ Research Assistant,
Instructional Design
and Technology,
Ohio State University

1993 ............................................................ Research Assistant,
Center for Teaching
Excellence,
Ohio State University

PUBLICATIONS


FIELD OF STUDY

Major field: Education

Studies in: Instructional design and technology
            Computer based education
            Qualitative methodology
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Chapter I

INTRODUCTION TO THE STUDY

Background

Eugene Ferguson, a historian of science and technology, has documented how the practice of a visual thought process has been a necessary component in engineering inventions and discoveries (Ferguson, 1977; 1992). Robert Root-Bernstein, a chemist, has documented how visual thinking skills played a significant role in the discoveries by many famous scientists such as the frequent drawing of an irregularly branching tree in the notebook of Charles Darwin (Root-Bernstein, 1985; see John-Steiner, 1985). However, the development of a visual thought process does not play a significant role today in the basic classroom curriculum (e.g., Eisner, 1985).

The role of visualization processes in education has been studied by researchers across different disciplines such as biology (e.g., Lord, 1987), mathematics (e.g., Bishop, 1989), and visual arts (e.g., John-Steiner, 1985). Research has focused on training and testing to improve visualization skills (e.g., Zavotka, 1987). Researchers have studied gender differences in visualization skills (e.g., Baenninger and Newcombe, 1989). Other
researchers have questioned the traditional techniques of assessment on visualization processes due to their multidimensional nature (e.g., Baker and Belland, 1988). Belenky, Clinchy, Goldberger, and Tarule (1986) suggest that the use of visual metaphors such as the ‘mind's eye’ should incorporate dialogue and interaction. Visual thought processes in activities encompass more than just abstract formalization of seeing, imagining, and drawing (McKim, 1980). Due to individual nature of the visualization processes, some researchers have also suggested and used qualitative approaches in understanding the use of visual imagery in mathematics education (e.g., Bishop, 1989; Yakimanskaya, 1991). By studying the visualization process—the how of visualizing—researchers hope to understand the nature and the extent of its use so that the visualization skills can be further facilitated in mathematics classrooms.

To understand visualization in the classroom, Michael Battista (1990) has also suggested detailed observations of instructional practices of teachers. Norma Presmeg (1986a) reports that the teachers who used visual methods in mathematics classrooms made connections between the students’ real world experience and the mathematics curriculum. It seems reasonable that teachers should help students incorporate their visual thought process into the conceptual knowledge (Battista and Clements, 1991). Such teaching practices provides the students with greater opportunities for thinking visually. Baker and Belland (1986) have gone so far as to provide a criterion for the selection of visual-spatial activities in the classroom to complement the curriculum. However, there has not been much research on the nature of visualization practice already present in classrooms. For instance, how (if
at all) does the teacher integrate (or support) the development of visualization process into the classroom curriculum? Studies on visualization development usually recommend what the teachers should do to develop their students' visualization process. Visualization practice that occurs in classrooms everyday has hardly been well studied.

Rudolf Arnheim (1986, p. 151) has said that "visual thinking is indivisible," which means that visual thinking must be encouraged in all areas of learning and teaching in the classrooms so as to create an environment where there are ample opportunities for the students to think and act visually. The process of visualization, then, must be studied as it is used in situ; that is, how it is embedded in actual tasks or activities in the classrooms everyday. Such a study would also provide an account of what counts as visualization to the students and teachers. The visualization process is closely connected to context of the activity (e.g., Yakimanskaya, 1991).

Research in visualization has been closely associated with mathematics education (Bishop, 1989). The National Council of Teachers of Mathematics in the United States has set a standard for elementary school mathematics curriculum to develop spatial sense in young children (Yackel and Wheatley, 1990). Mathematics educators in the former Soviet Union consider the development of spatial thinking in young children to be very important for all sorts of educational and professional activities (Yakimanskaya, 1991). The insights offered by the visualization research in mathematics education has been very useful to this study. Furthermore, researchers in the United States (e.g., Arnheim, 1969) and Israel (cited in Kanon, 1992) have suggested
introducing visual education into the school curriculum. Schools usually put emphasis on a prescriptive curriculum where the students are rarely given a chance to express themselves in non-verbal or non-mathematical modes. So, the development of different modes of thought, especially the visual mode of representation, becomes a "null curriculum" of most schools (Eisner, 1982, p. 63-68).

**Purpose of the study**

The purpose of the study was to explore, describe, and understand the phenomena of everyday visualization in elementary classrooms. To attain this purpose, the researcher studied how the process of visualization was embedded in everyday classroom activities. Three research questions guided this study.

- What are the everyday activities that rely upon the development of visualization abilities among students?
- How do teachers incorporate, if at all, visualization strategies in their teaching, classroom activities, classroom interactions?
- To what extent does the teacher rely upon her/his students' visualization skills? How does he/she motivate those who do not have such skills, or provide encouragement to those who need help to get started in using such skills?

Why study visualization in everyday classroom activities? Schools play an important role in the lives of the students. Much has already been said about school being a site that is not value neutral since schools—just as any other settings—are laden with social, cultural, political, economic, and historical interests (e.g., Suchman, 1993; Harley, 1991; Lave, 1988; Eisner
1985). To understand what is being learned and how it is being learned in the school classrooms, it is necessary to examine the nature of everyday practice in various instructional contexts in the classrooms (e.g., Resnick, 1991; Lave, 1991). In classrooms, the students travel from one instructional context to another drawing upon their local situated knowledges as it is appropriate to new instructional contexts or situations (Damarin, 1993).

Research on visualization skills tells us what visualization is and how it can be done, but this is without examining the interaction of the agent and context of the activity. Visualization as an everyday activity in the classroom has yet to pursued by researchers. To examine the work of everyday visualization processes in fourth and fifth grade classrooms in an Arts IMPACT school (see Chapter 4), it seemed appropriate to study these processes across many subject areas (such as science, math, and visual arts) as well as school extra-curricular activities (such as the chess club). The analysis of goal directed actions (Scribner, 1984a), such as the teacher describing the workings of the short circuit to the students through illustrations, allows us to understand the visualization process embedded in everyday classroom activity.

Examples of data representing everyday visualization

Sylvia Scribner (1984a; 1984b; 1986), using the framework of Soviet activity theory, has suggested that to understand the nature of practical thinking ("mind in action") one's unit of analysis must be the activities where thinking is embedded and not in the isolated mental tasks. Scribner studied how workers fill orders in a dairy. One of tasks of the dairy workers was to
pack containers of different sizes into the plastic cases. The workers had to use their mathematical knowledge and spatial knowledge to organize their work in the dairy. Here, a worker (preloader) describes how he filled an order for half a case (1984a, p. 26).

Preloader: I walked over and I visualized. I knew the case I was looking at had ten out of it, and I only wanted eight, so I just added two to it...I was throwing myself off, counting the units. I don't never count when I'm making the order. I do it visual, a visual thing, you know.

Scribner (1984a, p. 27) notes that the preloaders used their perceptual skills for visual inspection of the cases, and she suggests that their “seeing” may be similar to the master chess players who are able to perceive meaningful relationships of the chess pieces on the chess board more easily than the novice players (Chase and Simon, 1973).

Barbara Rogoff (1984), who studied thinking and learning in social contexts, suggests that “everyday contexts of thinking—at home, in school, in the laboratory, or wherever—involves an emphasis on the purposes for which people engage in activities and the pragmatic considerations involved in people's solutions to problems” (p. 8). Everyday activities in the classroom must be taken seriously since students spend a significant portion of their time in it. Shaun Harley (1991), who studied how third and fourth grade students did math word problems, suggests that “students in the classroom are situated thinkers as they engage in classroom activity” (p. 2).

In other words, as Lave, Smith, and Butler (1988) point out, we must recognize the classroom "as a socially situated production of everyday activity" (p. 77).
To study the visualization process—the how of visualizing—it would be useful to understand the ways students incorporate visualization skills/strategies in a more contextual basis in the classrooms. For instance, let us look at two short instances of visualization in everyday activity. In a reading period the class was assigned the reading, *Chester Cricket's Pigeon Ride* by G. Selden [10-13-92]. Ms. Trudy Parker (TP), a fourth grade teacher, told her students: “Close your eyes and think about the Chester Cricket way up in the air looking down at New York City.” She suggested seeing a tree growing and small buildings. She invited her class to “try and visualize” in their heads. The students participated to create a list on the board as part of their pre-writing (brainstorming) in the class on what they “saw” and this list included things such as sewer lids, cars zooming by, pale colored umbrellas, police calming person, etc. TP asked her students to pretend that they “are floating on a hot air balloon.” The students started to write a descriptive paragraph but had to continue the next day. The next day, TP provided instructions again on this class activity [10-14-92].

TP: You will be writing about what you see from way up high. The things that we put up on the board will help you. You will be writing about what you see. But, you could also write about your feelings. Are you excited? Are you scared? Are you worried about falling? Do you like this feeling? Do you feel you could fly? Write about your feelings too. Two things: what you see or maybe what you hear. Maybe what it smells like way up there? Is it a crisp fall day? Is the sun out? Is it cloudy? Are you chilly because you are way up in the clouds? So, think about those things.

In another instance, Cathy had written a paragraph about her walk on the beach. “Your imagery is beautiful,” wrote TP on Cathy’s paper. During a
lunch period Cathy pointed out how she used imagination to do her writing [1-20-93].

Cathy: I just imagined that I was on a beach and it started to rain. That has happened to me before. So, I was just thinking of what's happened to me, but I made up a little.

A Walk On The Beach

I was walking along the beach one day collecting shells when all of a sudden it started to rain. A man came up behind me, invited me in and blinded me from the cold and rainy day. His wife scurried in, terrified but calm when she saw me. She sat down and talked to me. Her words were like roses in the middle of a patch of weeds. After that the rain cleared up and I went home.

Figure 1. Cathy's descriptive paragraph.

TP frequently uses words such as "visualize" and "imagination" in her class. When I asked Carol what she understood when TP used such words in the class, she said [1-20-93]:

Carol: I thought that [TP] thought that if we used our imagination and shared it, she would see what we were thinking of it. What did you do in your task, or if what's happening to you because your imagination might, say like Cathy's story: you might like imagine yourself or if you visit the beach, you imagine the beach and you imagine a rainstorm and then you imagine the rest.

Reading and writing descriptive paragraphs is part of this fourth grade class everyday activity. After the circle meeting everyday, the reading period
begins. The two brief episodes cited above show how students in TP's class are led through thinking visually. Students experience all sorts of images and ideas and learn to share them with others (e.g., Hortin, 1983). Visual thinking skills are developed within the context of the classroom curriculum (Arnheim, 1986; Casey and Wolf, 1989).

**Significance of the study**

Visualization is an alternative way of thinking that is not commonly used in our educational system. (Hortin, 1983, p. 21)

This study is significant in various ways. First, it provides a summary of the visualization research from different perspectives (such as gender and visualization and testing and training in visualization) to develop a rationale for an everyday visualization study in the classrooms. It, thus, recognizes everyday classroom activity appropriate and important enough for understanding the nature of the visualization process.

Secondly, it uses a qualitative approach for the study of visualization process rather than the traditional psychometric approach. This was necessary to study the interaction of students and teachers in various instructional contexts in the classrooms. This approach allows for using different data gathering techniques (such as audio-video recordings and informal interviews) to examine how visualization is accomplished in the classrooms everyday; it also documented what the students and teachers consider as visualizations. The researcher recycled evolving data descriptions with the teacher participants and this allowed the teachers to
become more conscious, not only of their (and of the students') visualization process, but also of their teaching practices.

Finally, this study, based on its data descriptions, suggests how instructors organize visualization in the classrooms. Further research expanding on this study is also suggested.

**Use of a qualitative approach**

This study used a qualitative approach to understand everyday visualization in the classrooms. In traditional experimental studies, context of the activity is thought to be independent from the task. The everyday visualization process in the classroom is influenced by the instructional context and so it must be studied within this context in the natural setting. As mentioned before, a qualitative approach facilitates the study of visualization embedded in the classroom activity. The use of qualitative research to study visualization has also been suggested by Yakimanskaya (1991) and others.

A preliminary study was conducted and this guided the dissertation research especially the developing of a framework for the everyday visualization study and for data collecting and analysis procedures. The methodology of this study is presented in Chapter 3. Participant observation was one of the major sources for data gathering in the Arts IMPACT elementary school. In this school, the Arts are infused into the basic classroom curriculum [see Chapters 3 and 4 for school description]. I asked about the connection of the Arts to the subject areas to Mimi and Beth, two fifth grade students [12-14-92].
Mimi: It's real fun to transfer what you are learning into art, drama, music or whatever. Like you are learning about Africa and you sing African songs and do African stories and plays in drama. I love that.

Beth: Yeah and when you really get to see what you can draw and see what you can do, I mean, it's fun because sometimes you never know that you could draw stuff like that. Like Mimi said that when you talk about Africa, you would go into art and draw Africa or something like that.

Mimi: Or you talk about certain animal and you draw it. It's fascinating and it's a different way to learn instead of reading out of a book or something all the time.

Beth: That's what I love about [this school].

Data were collected from the school classrooms in the forms of audio and video tapes, field notes, informal interviews, and classroom documents. Data analysis was on-going with the data gathering period and took into consideration the contextual information to make sense of the everyday visualization in various classroom situations. The study also followed the validity guidelines offered by Patti Lather (1986a) to guard against researcher bias.

I look at the issue of credibility of the researcher in Chapter 3. Here, I take the opportunity to provide some insight about myself to the reader. Like the Balinese people (Bateson and Mead, 1942, p. 84), I too have found visual and kinesthetic learning most helpful whether it is learning how to square dance or trying to conceptualize the process of photosynthesis in my mind. Also, it is easier for me to externalize my thoughts through diagrams and drawings. I was introduced to field of visualization research through an independent study project under the guidance of my advisor, Professor Belland. For my independent study, I did a review of gender differences research in visual-spatial skill instruction which I presented at the
International Visual Literacy Association meeting (Thakkar, 1991). As I continued to read and catalogue the literature on visualization research (and conversed with Professor Belland and Professor Damarin on this research area), I realized that an extensive examination of the visualization process in the classroom had not been done. The qualitative methodology courses which I had started to take at this point also inspired me to study the visualization practice in the classrooms everyday. Professor Damarin had also suggested once that through a qualitative approach I could get a sense of the ways in which the visualization process is important to teachers and students. The insights I would gain from studying visualization practice in the classrooms might later come useful in the design of curriculum, instruction, tests, and computer software.

Limitations of the study

This study was conducted in an Arts IMPACT alternative elementary school. While this research setting was appropriate for an everyday visualization study in the classrooms, it also created a problem. The Columbus Public Schools system only has one such Arts alternative school. So, this setting does not represent other elementary schools insofar as the Arts are infused into the basic academic curriculum. Furthermore, the teachers did not (nor were they asked to) modify their subject schedules to fit the researcher's objective; instead, the nature of visualization practice was examined from what was generally happening in the classrooms everyday. This study did not focus on issues surrounding gender and visualization in classrooms everyday.
Organization of the chapters

The background and the purpose of the study are presented in the first chapter. The significance and the limitations of the study are presented along with the use of a qualitative approach. The second chapter provides the literature review. It presents the background on visualization research in various aspects. The framework for everyday visualization study is then presented. The third chapter describes the methodology used in the study. It describes the features of participant observation. Descriptions of the participants, research setting, data collection, data analysis, and validity are given. The fourth chapter describes the school and provides the descriptions of everyday visualization in many subject areas from one fifth grade classroom and two fourth grade classrooms. A discussion on the visualization in the classrooms is also provided. The fifth chapter provides the conclusions and recommendations of the study. It relates visualization to everyday classroom activity and it states instructional implications based on the data descriptions.
Chapter II

REVIEW OF LITERATURE

This chapter has two main objectives. First is to present a review of research in visualization. Here, I provide a brief background in visual imagery and review research on testing and instruction in visualization skills. I also discuss gender related issues in visualization. Then, I present recent research in visualization in classrooms and discuss visual thinking through the visual arts. The second objective of the chapter is to put forth an argument for framing an everyday perspective for visualization study in classrooms.

Background in visual imagery

Humans have used visual-spatial modes of representations dating back at least to the Ice age (White, 1989). Francis Galton (1880) carried out one of the earliest studies on imagery. He tried “to define the degrees of vividness with which different persons have the faculty of recalling familiar scenes under the form of mental pictures, and the peculiarities of the mental visions of different persons” (p. 21). Galton reported that a great majority of the British scientists he had questioned thought in terms of words and not
images. Galton argued that many of these scientists may at one point have had the visualizing faculty, but it had been lost by disuse.

L. L. Thurstone (1938) in his study of Primary Mental Abilities identified a factor which he described as a “visual or spatial in character” (p. 79). There has been a long debate in cognitive psychology on the question whether mental imagery is visual or spatial (see Farah, 1988). Farah, Hammond, Levine, and Calvanio (1988) argue from neuropsychological data that imagery has both visual and spatial modes of representation “in that imagery is not exclusively visual or exclusively spatial” (p. 458).1 The visual representations are modality-specific which depict the literal appearance of objects such as perspectival properties, color information, and aspects of form, while spatial representations are abstract representations not sensory specific which preserve the spatial properties of the objects with respect to the viewer and to each other. Research in cognitive psychology has also shown that congenitally blind subjects are able to perform normally on imagery tasks and this suggests that visual information is not an essential aspect of imagery (Kerr, 1983; Farah et al., p. 441). This suggests that representations used in imagery must have spatial properties. Normal subjects, then, have a choice of using visual or nonvisual spatial representations for their imagery tasks (Farah, 1988, p. 315). Howard Gardner (1983), using evidence from spatial studies with blind subjects,

1 Physiological evidence suggests that two hemispheres of the brain excel at two different modes of thought processing—analytical/logical thinking in the left hemisphere and spatial tasks/artistic endeavors in the right hemisphere. Ronald Finke (1989, p. 147-148) reports from neurological evidence that although spatial relations and recognition of visual shapes and patterns is localized in the right cerebral hemisphere, the process of generating a mental image seems to be a left cerebral hemisphere function.
suggests that spatial representations can also be accessible through tactile experience (p. 186).

Kosslyn, Margolis, Barrett, Goldknopf, and Daly (1990) describe four aspects of visual imagery: image generation (the ability to form an image of a scene or object), image maintenance (the ability to retain an object), image scanning (the ability to scan one's attention over an image), and image rotation (the ability to transform or manipulate an image). The image generation and maintenance tasks make use of the visual sense while the scanning and rotation tasks make use of the spatial sense. In studying age differences in imagery, the authors report that while young children are poor in scanning, rotating, and generating objects in images they are good in maintaining images. Young children also seem to use static imagery for visual thinking (Piaget and Inhelder, 1971). Kosslyn et al. also report that females are generally superior in generating and maintaining images while males are superior in spatial abilities (see section Gender and Visualization, page 19).

From her studies on visualization in high school mathematics, Presmeg (1986b) defines a visual image as “a mental scheme depicting visual or spatial information” (p. 297). Presmeg argues that “this definition is broad enough to include kinds of imagery which depict shape, pattern, or form... [and] imagery which attains the vividness and clarity of a picture is also included” (p. 297). Alan Paivio (1979) argued that people may use two different codes—imagery and verbal—both to store and retrieve information. Paivio's dual-coding theory suggests that pictures are easier to remember than words since one can use both codes for recall. Vasu and Howe (1989)
report that children represent more information in pictorial form than in verbal form, and they also suggest that while "seeing is better than hearing, [the] combination of seeing and hearing is the best" (p. 407). It should be noted also that visual metaphors such as the 'mind's eye' suggest a static reality and connote that "disengagement and objectification are central to the construction of knowledge" (Belenky, Clinchy, Goldberger, and Tarule, 1986, p. 18; see Keller and Grontkowski, 1983). Visual metaphors should encourage dialogue and interaction between the subject and the object.

**Visual-spatial skills research**

Spatial ability usually refers to skills which involve transforming, manipulating, generating, representing, and recalling symbolic, nonlinguistic information (cf. Linn and Petersen, 1985, p. 1482). Spatial ability is a psychometric construct to study human performance. Eliot and Smith (1983, p. 1) place the history of descriptions of spatial ability research activities in three phases: "In the first phase (1904-1938), researchers investigated the evidence for or against the existence of a spatial factor over and above a general factor of intelligence. In the second phase (1938-1961), they attempted to ascertain the extent to which spatial factors differed from one another. And in the most recent phase (1961-1982), researchers have attempted to designate the status of spatial abilities within the complex interrelationships of other abilities, and to examine a number of sources of variance which affect performance on spatial tests." The present decade (1982-1992) may be considered as the fourth phase where researchers have made efforts through testing and training to understand how
individuals can improve their performance in visualization skills (e.g., Baker and Belland, 1986; Heinrich, D'Costa, and Blankenbaker, 1988). Researchers have also studied the gender differences in visualization skills (e.g., Linn and Petersen, 1985; Baenninger and Newcombe, 1989).

This section has identified three areas of research: spatial development, gender and visualization, and testing and instruction in visualization.

Spatial development. Jean Piaget conducted extensive studies on spatial development processes from birth up to the age of twelve (Piaget and Inhelder, 1956; 1971). John Eliot (1987, p. 100-108) summarizes Piaget's model of spatial development using four general assumptions. The first assumption is that our representation of space evolves from internalization and coordination of actions. In other words, activities (or actions) define our space. The second assumption is that spatial knowledge evolves in four stages: sensorimotor, preoperational, concrete operational, and formal operational space. Each of these stages is qualitatively different from the preceding ones, and yet each unites the preceding stages as a preparation for the next stage. The third assumption is that there are three classes of spatial relationships: topological, projective, and Euclidean. The fourth assumption is that imagery is an important component in spatial representation, for through imagery a child can develop the ability to perceive and to imagine an object from different viewpoints. Several other researchers such as Jerome Bruner also had insights on spatial developmental process (see Eliot, 1987). For instance, Seymour Papert introduced a computational perspective to the spatial development process,
which suggests breaking down of knowledge into “mind-size bites” (1980, p. 171). Piaget for the most part ignored the role of social context in the child’s development (Rogoff, 1990).

Developing spatial thinking among school children is considered a high priority among Soviet educators. Wilson and Davis (1991) list six common propositions of Soviet research (cf., p. xiii): 1) Spatial thinking develops through activities. 2) An individual must create her/his own image before it can be used in spatial thinking. 3) Representations and representational systems are a necessary component of spatial thinking. 4) There is a need for qualitative research to study spatial thinking. 5) Many individual differences exist among students in spatial thinking. 6) Spatial thinking is a dynamic process as images are manipulated to form new images. I. S. Yakimanskaya (1991) points out that spatial thought processes of students “are developed mainly within the framework of graphic and visual materials while solving classroom problems by recalling images from memory” (p. 27). The image in spatial thinking is mediated by activity since it is created “under the influence of two closely interconnected determinants: visual stimuli and activity required by the conditions of the problem” (p. 43).

*Gender and visualization.* Performance on visual-spatial tests has been correlated with success in many occupations and subject areas (e.g., McGee, 1979). The United States Employment Service considers visual-spatial ability to be predictive of success in four job categories: engineers, scientists, drafters, and designers (cited in Bertoline and Miller, 1990). Many studies report that females have more difficulty on visual-spatial tests than
males (e.g., Maccoby and Jacklin, 1974). Studies in physics (e.g., Pallrand and Seeber, 1984), chemistry (e.g., Carter, LaRussa, and Bodner, 1987), and biology (e.g., Lord, 1987) report that there is a distinct correlation between visual-spatial abilities and performance in science courses. Low-ability students who take introductory level science or geometry courses often find their visual-spatial abilities enhanced. C. E. Lunneborg and Lunneborg (1984) report that everyday abilities most related to three-dimensional spatial visualization were: understanding mathematics and science, understanding graphs and objects, drafting and drawing things, and arranging objects.

Visualization ability is often considered by researchers (e.g., P. W. Lunneborg and Lunneborg, 1986) as a measure of success in science and technical fields. However, meta-analysis of visual-spatial research on gender differences "reveal that (a) gender differences occur on spatial processes not obviously related to science or mathematics, (b) gender differences in spatial ability are declining, and (c) processes revealing gender differences in spatial ability respond to training" (Linn and Hyde, 1989, p. 18). In their meta-analyses, Linn and Petersen (1985, p. 1482) partition studies into three categories of spatial processes: spatial perception, spatial visualization, and mental rotation. They report that gender differences are large on mental rotation tests, medium on spatial perception tests, and small on spatial visualization tests (p. 1491). Furthermore, training reduces gender difference in mental rotation scores (Lohman, 1988). Linn and Hyde (1989, p. 19) report that gender differences on mental rotation tests occur on speed and not on accuracy. Also, the most
recent meta-analysis by Baenninger and Newcombe (1989) reports that: 1) Prior participation in spatial activities in and out school is related to higher spatial test scores. 2) Spatial training can strongly improve spatial scores for both sexes. Baenninger and Newcombe (1989) suggest that future work examine "the relationship between spatial activity participation and spatial ability in school-aged children" (p. 342).

Newcombe, Bandura, and Taylor (1983) argue after reviewing the literature on spatial abilities that activities which are considered spatial are more often masculine than feminine. They suggest that "feminine" activities such as sewing should be considered as well, since they too involve spatial skills. Stephen Jay Gould (1981) has pointed out how such objective tests have a predetermined bias against women. David Nakaji (1991), who studies visualization in physics classrooms, points out that appropriate visual metaphors should be selected to present concepts in physics to women students. It should also be noted that there is no one set way to visualize since different people may process an image in different ways. It does seem that the visual-spatial experiences of some are socially constructed to be inferior and not simply different (Harris, 1989, p. 22; Belenky, Clinchy, Goldberger, and Tarule, 1986, p. 191-193).

Testing and instruction in visualization. Mark McGee (1979) in summarizing the research in spatial abilities defined visualization as an "ability to mentally manipulate, twist, or invert a pictorially presented stimulus object" (p. 893). Test instruments are thought to be definitive in evaluating an individual's visualization ability. In disciplines such as engineering design, visualization
ability is considered necessary (see Ferguson, 1992). Eliot and Smith (1983, p. 11) divide spatial tests into two categories: recognition and manipulation. In the recognition division are the tasks (such as embedded figure) that require “the perception and retention of visual forms.” The manipulation division contains tasks (such as mental rotation) that appear to require “the mental manipulation of visual shapes.”

Heinrich, D'Costa, and Blankenbaker (1988) suggest that when examining visual-spatial abilities it is unwise to “select a readymade test purely on the basis of its statistical qualities” (p. 4). So, for selecting engineering students Heinrich et al. developed a spatial-visualization test after identifying the domain of spatial skills needed for success by students and faculty in engineering graphics. Two major skills were identified in this multiple-choice test: visual synthesis and decomposition. Four other skills were identified within these two major skills: pattern recognition, two-dimensional versus three-dimensional visualization, ability to mentally move images, and ability to see an object from different directions (rotation method). This test also offers diagnostic feedback for remediation to engineering graphics students. D. F. Lohman (1979) points out that “people do not solve [spatial tests] in the same way. Further, we cannot say that some people use one set of mental processes to solve a spatial problem while others use a different set because people do not solve all items in the same way” (cited in Eliot and Smith, 1983, p. 13). Also, Baker and Belland (1988) point out that often assessment in visual-spatial learning is problematic since students using such processes are unable to
communicate in traditional ways. This is so since “visual-spatial learning is multidimensional and simultaneous” (p. 16).

There is evidence that visual-spatial skills can be developed among children through computer activities (e.g., Belland and Trethewey, 1989). Ben-Chaim, Lappan, and Houang (1988) in studying the effect of instruction in spatial skills to middle school boys and girls report that “spatial visualization ability is a trait, once acquired, [which] can be further developed” (p. 67). They suggest that seventh grade is an appropriate grade level for spatial instruction. Smith and Litman (1979) suggest that pre-puberty may an optimal time for spatial instruction. The structure of activities in spatial instruction is also important. Baker and Belland (1986) suggest that spatial activities should be applicable to the regular school curriculum and they offer criteria for selection and development of spatial skills (p. 5-6):

1) Spatial activities must assist in acquisition of specific science and mathematics concepts. For example, interpretation of perspective line drawings. 2) Spatial activities must have strong appeal to female learners. 3) Spatial activities must be integrated in the curriculum as a substitute for regular activities.

Before integrating spatial thinking activities in school curriculum (Baker and Belland, 1986; Yakimanskaya, 1991), it seems reasonable to study a prior question: What are the everyday activities in the classrooms that rely upon development of visualization abilities among students? Research in visualization tells us what visualization is and how it can be done. This, however, is without examining the interaction of student and the context of classroom activity. Testing situations may also prevent the development of
spontaneous visual imagery in people due to the very controlled nature of formal testing procedures. Martin Lindauer (1983) suggests that study of visualization skills must take into account the involvement of the participants with the visual arts. This may provide us with a direct observation of the individual's internal forms of representation (John-Steiner, 1985).

The next section presents recent research in visualization in classrooms, and also discusses visual thinking through visual arts.

**Visualization in classrooms**

In his review of visualization in mathematics education, Alan Bishop (1989) points out that "[t]he 'noun' of visualization directs our attention to the product, the object, the 'what' of visualization, the visual images. The 'verb' of visualization on the other hand makes us attend to the process, the activity, the skill, the 'how' of visualizing" (p. 7). From his review, Bishop suggests "that the psychometric approach is not appropriate for studying the visualization process" (p. 10).

Presmeg (1986a) in her study of high school mathematics classified students as visualizers and nonvisualizers depending on their visual or nonvisual methods of solution to the given mathematics problems. She found that the visualizers used different kinds of imagery and she classified these images into five categories (cf., p. 43-44): pictorial imagery (seeing the 'picture-in-the-mind'), pattern imagery (finding patterns—visual-spatial relationships), memory images of formulae ("saw" the formula in the mind), kinaesthetic imagery ("walking" through imaginary points with fingers), and dynamic imagery (using moving image). Presmeg (1986a; 1992) points out
that pictorial imagery category created one-case concreteness of an image or diagram due to the particular nature of an image picture or diagram. This was one of the major difficulties experienced by visualizers for the 'picture-in-the-mind' may “prevent abstraction and generalization if essential features cannot be separated from the random ones” (p. 7). Presmeg (1992) points out the importance of pattern imagery in reasoning, abstraction, and generalization of mathematical concepts. In pattern imagery concrete details—such as the ‘picture-in-the-mind’—are disregarded, instead relationships are depicted in a visual-spatial scheme.2 3 Facilitation of

2 One example of pattern imagery is in the game of chess. Chase and Simon (1973) argue that the skill of the master is not in visualizing vividly but at perceiving meaningful but unfamiliar patterns. The 'mind's eye' in chess may provide spatial relations and physical relations of pieces on the board. The chess master may "see" things on the board which are not evident to the novice player.

A word about the ‘mind's eye’ is also in order here. Simon and Jing (1989) argue that two forms of imagery operate together as the ‘mind's eye’. "One form is a raster of discrete points that operates as a 'photograph' of a diagram or picture, and from which symbolic processes can extract features ... A second form of representation of images employs symbol structures in [such] a way that nodes correspond to elements in a diagram or picture, while the links correspond to the spatial relations among these elements" (p. 23). Mental images can be manipulated at will by the imager and so the 'mind's eye' has an advantage over external diagrams (p. 24; also see Larkin and Simon, 1987). Belenky et al. argue that the 'mind's eye' suggests a static reality and "promote the illusion that disengagement and objectification are central to the construction of knowledge" (p. 18). Is there any interaction between the subject and object? Ferguson (1992) gives a broader perspective: "the mind's eye is the organ in which a lifetime of sensory information—visual, tactile, muscular, visceral, aural, olfactory, and gustatory—is stored, interconnected, and interrelated. We get to know things through a series of sensual interactions: bumping, smashing, touching, smelling, dropping, lifting, and so on. The arbiter of all these experiences is the mind's eye. Through it, we make sense of the physical world we inhabit" (p. 42).

3 A word about the ‘picture-in-the-mind’ metaphor is needed here. Stephen Kosslyn (1980) points out that mental images are not like pictures but instead are quasi-pictorial; that is, they resemble pictures in several ways while lacking some of their properties. There is a presence of spatial and perceptual features in mental images (Finke, 1989). Zenon Pylyshyn (1973) disputed that mental images are stored in a raw uninterpreted form resembling photographs, instead he argues for ordered propositions which state relationships and facts. Samuels and Samuels (1975) define visualization, in context of spirituality and healing, as "creating a mental image, creating a picture in the mind, seeing with the mind's eye. [M]ental images more resemble thoughts and ideas than sights" (p. 121). In this research, however, Pylyshyn’s argument is not considered in light of the recent imagery research (see Finke, 1989).
pattern imagery by teachers who use visual methods "would obviate some of the difficulties associated with the one-case concreteness of imagery" by visualizers in the learning of mathematics (Presmeg, 1986a, p. 45).

Presmeg points out that some teachers who use visual methods try to make connections between the mathematics curriculum and the students' real world experience. This connection is different from "connected teaching" (Belenky, et al., chapter, 10) which means, in part, to "enter into each student's perspective" (p. 227). Such a practice makes teaching primarily interpersonal and provides further opportunities to students for visual thinking. Connected classrooms facilitate the sharing of individual perspectives through discussions. The teacher in the connected classroom carries authority which is based on cooperation with the students. The connected teacher often acts as a midwife as she encourages and assists her "students in giving birth to their own ideas, in making their own tacit knowledge explicit and elaborating it" (Belenky et al., p. 217).

Bishop (1989) suggests that the visualization process entails the student constructing "some kind of visualization and using it appropriately" (p. 10). He argues that in the mathematical problem-solving context, "appropriately" usually means "to help obtain a solution." Students may create and use visualizations differently and so it is necessary to encourage diversity in the use of visualization process in the classrooms. A broader notion of the visualization process then must be taken than that which entails the usual "problem-solving." One way to attain this is to promote visualization activities into mathematics curriculum which allow the students to create their own meanings. Yackel and Wheatley (1990) describe how students
often create their own meanings and make their own discoveries in visual activities when they work with manipulatives, figures, or line drawings. It helps if in these classrooms there is a dialogue and an interaction between students and teacher as in the "connected classes" (Belenky et al., p. 219-223).

Presmeg (1986a) considers visuality to the extent that it involves the formation and use of visual imagery in the classroom by teachers or students. Soviet mathematics educators go further in the pedagogical understanding of visuality (Antonovskii, Boltyanskii, Volovich, Krass, and Levitas, 1990). Antonovskii et al. suggest that the concept of visuality has two characteristics: "isomorphic reflection of the essential features of the phenomenon and simplicity in perceiving the model" (p. 9). To use their example (p. 9), consider a wooden block which serves as a model of a rectangular parallelepiped. Although this model is not a rectangular parallelepiped in a mathematical sense, it has the same number of edges, faces, and vertices, and shares the same spatial and physical relations. This is isomorphism. Also, this wooden block is simple enough to be perceived by the students. So, we can say that this wooden block has the property of visuality. A. M. Leushina (1991), another Soviet educator, suggests that the visuality of young children changes and becomes more complicated with the development of thought. Visuality for young children is first expressed through concrete objects and later with further development can be expressed through models, charts, or diagrams. Visuality, Leushina argues, "is not an end itself, but rather a means of gaining a deeper knowledge of the world" (p. 165). Leushina's visual principle of teaching is similar to the
“connected classroom” in so far as the teaching brings about the unity of words (interaction and dialogue) and visual aids (representational and natural) which “leads to a connection between the object (image), the word, and the action” (p. 166).

From this research, it seems reasonable to explore these questions: How is the process of visualization embedded in the classroom activities? How do teachers incorporate visualization skills in teaching of the subject areas? What dialogues and interactions concerning the visual take place among the classroom participants: teachers and students?

Visual thinking through visual arts. Elliot Eisner (1985) argues that cognition in today’s educational discourse is often referred to as thinking in either a mathematical mode or a linguistically-mediated mode; other modes, such as visual and auditory forms of expression are often neglected and this says Eisner, “biases the criteria through which human competence and intelligence are appraised” (p. 99). Eisner (1991) asserts that “if visual arts teach one lesson, it’s that seeing is central to making. Seeing, rather than mere looking, requires an enlightened eye: this is as true and as important in understanding and improving education as in creating a painting” (p. 1). Root-Bernstein (1985) gives an elegant discussion of scientists who in their youth actively participated in the visual arts and suggests that lack of exposure to visual arts in schools may limit visual thinking of their students. Many schools have developed a curriculum to accommodate the role of understanding in the visual arts and the students finishing such schools are able to think and act upon various visual forms of expression (e.g., Gallas,
1991; Grallert, 1991). Millman and Speranza (1991) suggest that visual arts may help in introducing concepts in geometry (such as lines and points) and make it less abstract to students (see Slawsky, 1977). Such a curriculum creates an everyday classroom in which it is natural to think visually. McFee and Degge (1977) argue that students who develop visual skills early on have a higher potential for learning and experiencing in subject areas (such as mathematics, language arts, and sciences).

Gardner (1991, p. 145-146) argues that there are two ways for representing knowledge for young children: (1) the sensorimotor way of knowing where a child comes to understand the world through her/his senses and actions, and (2) the symbolic form of knowing where a child comes to understand the world through the different symbol systems he or she uses. Children learn how to work back and forth between these ways of knowing and how to integrate them while carrying out a task at hand. But, what is this understanding? D. N. Perkins (1988) provides five characteristics of understanding (p. 114-117):

- Role of relations in understanding—Understanding is considered to be a web of relationships between different things (or concepts) so as to provide them with meanings. For example, to understand a work of art involves knowing form, period, etc.
- Role of coherence in understanding—Understanding a concept or a thing also involves knowing if the web of relationships is “coherent in itself and with the world outside the [individual]” (p. 115).
- Role of standards of coherence—A poem may have paradoxes, but a theory of physics ought to have none. So, the standards of coherence of understanding might vary from context to context.
• Role of generativity in understanding—A person should not only know about the web of relationships but should also be able to act upon these relations “in response to the demands and opportunities of the moment” (p. 116).

• Open-ended character of understanding—Understanding is really an unending quest; that is, the web of relationships grows continually.

So, what does visual arts have to do with understanding? Perkins (1988) argues that the visual arts engage “our psychological resources of understanding” (p. 111). When we do a role-play or see a painting, we decode, encode, construct, operate, etc. through a web of relations. For instance, to understand Georges Seurat’s Sunday Afternoon on the Island of La Grande simply looking and seeing is not enough and “until one understands what sorts of things one might find by looking deeper, one has no ready way of knowing that one is missing anything” (p. 120).

Visualization activities such as role-play also engage students in reading texts and this reader-text relationship is dynamic (Karolides, 1991).

**Framing an everyday perspective for visualization study**

It has been argued in the previous sections that the process of visualization has traditionally been studied without examining the interaction of the student and the context of classroom activity. It is reasonable then to study how visualization is embedded in everyday classroom activities. For one thing, this would certainly enhance our understanding of the visualization process. What are these “everyday” phenomena and why should visualization in classrooms be studied under that label? A discussion is presented here. It is argued that these everyday phenomena
of the visualization process are very much situated in the classroom life. But first let us review some issues surrounding learning in school classrooms.

_Schooling._ Lauren Resnick (1987), in her presidential address to the American Educational Research Association, provided three reasons why school learning differed from out-of-school learning. First, schooling focuses on individual thought and performance and the use of tools (e.g., external props) are usually not encouraged. In contrast, out-of-school learning relies heavily on tools which are usually dependent on the activities. Second, learning in school focuses on symbolic performance separated from any meaningful context. This is based on the belief that mental capabilities lie only in individual minds. On the other hand, out-of-school learning is intimately connected with the available objects and events. Study of out-of-school learning suggests efficient use of the environment. For instance, Scribner's (1984a) study in the dairy demonstrated how workers used the warehouse physical space efficiently to organize their work. Harley's (1991) study of third and fourth grade students doing math word problems shows how students used objects present in the situations to think with when solving math problems. Here, Steven (S), responding to the researcher's (R) question, uses the available object information to facilitate his understanding of the baking process (Harley, 1991, p. 147).

R: Here's a measuring cup and Bran and Flour. How would arithmetic and numbers help you do the kinds of things you would do with these materials?

S: Well, it would help you do the microwave directions. So if you want four servings you'd need one and one third cup. (Reading from the box) That is one of these (using
measuring cup) and up to there (pointing to one third of a cup measure). And then you’d need four of these. And then you’d go get a tablespoon of salt. You could really not do that because that says optional, so you might not use it.

Scribner (1986, p. 25) suggests that the efficient use of objects and situations suggests two implications: (a) becoming skilled in any domain may be about moving from the concrete to the abstract which is opposite of what has traditionally been suggested by psychological learning theory and (b) models of thinking that only deal with representations in the head may find practical thinking problems intractable.

Finally, while out-of-school learning is based on situation-specific competencies, school learning focuses on "general, widely usable skills, and theoretical principles" (p. 15). How can schooling then be revised to accommodate learning that is found out-of-school? Resnick (1987; 1989) provides features that she found in successful school programs which incorporate the characteristics of out-of-school learning. Many of these effective school programs use features of apprenticeship to encourage student observation and commentary by externalizing what are usually the hidden processes. These programs encourage joint social participation in tasks. Also, these programs are organized around subject matter knowledge and interpretation rather than generalized learning.

Many researchers (e.g., Brown, Collins, and Duguid, 1989a; Lave, 1990, 1991; Rogoff, 1990, 1991; Lave and Wenger, 1991) have discussed the application of the apprenticeship model to school learning. Lave and Wenger (1991) argue that school children are kept from participating peripherally in activities. Unlike in an apprenticeship (such as in a tailors'
apprenticeship) where the new apprentices participate within the community of practice before become master practitioners, school classrooms usually do not reproduce a community of practice. For example, high school physics students do not participate in the community of physicists. Brown, Collins, and Duguid (1989a) suggest that classroom activities are not authentic activities since they fail to provide appropriate contextual features. Authentic activities are considered to be the ordinary practices of the culture of readers, mathematicians, artists, and so forth. Brown, Collins, and Duguid (1989a) then go on to say that what students do in the classrooms “tends to be ersatz activity” (p. 34). How can the schools then provide authentic practice? Brown, Collins, and Duguid (1989b), for instance, suggest that schools can “put the students in presence of authentic practice, where the students can watch and work with people playing, exploring, and experimenting with ideas historically or mathematically” (p. 11).

The curriculum in an apprenticeship differs from the classroom curriculum. The school curriculum usually tends to be like a teaching curriculum rather than like a learning curriculum (Lave and Wenger, 1991). A teaching curriculum is organized to provide instruction to the students for “there is no learning without teaching and that what is taught is what will be learned (if it gets learned)” (Lave, 1990, p. 310). On the other hand, a learning curriculum is situated in practice since it evolves from the participation of the learners in that community of practice and the “learners know clearly what the curriculum is, and it organizes the basic outlines of their everyday practice but does not specify what they should do or precisely how to do it” (Lave, 1990, p. 314). Activity in a learning curriculum is
dilemma-driven as it is based on the learner's understanding in practice. A learning curriculum allows learners to "own" the problems to be solved.

*Everyday activity.* Jean Lave (1988, p. 15) suggests that everyday activity describes the routine character of activity of an individual. This routine character in the classroom sphere is socially constructed by the participants—teachers and students. It must be noted, however, that the label "everyday" can have a negative connotation and stands frequently in contrast to scientific thought. For instance, math in everyday life (such as in the supermarket) where it is dilemma-driven is thought to be distinct from the "real" math which is done in classrooms (Lave, 1990). Lave and her collaborator, Michael Hass, studied the mathematics practice in a third-grade classroom where they focused on a group of 11 children (Hass, cited in Lave, 1990). Hass found that while the teacher and the curriculum prescribed what the everyday practice of the students should be, the students produced their own practice. The teacher prescribed procedures for doing multiplication and division but the students did not adopt these prescribed procedures. The students worked out the math exercises using their own methods (through collaboration with each other and by inventing procedures), but when the students turned in their worksheets they

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4 A "great divide" theory suggests a distinction between "scientific" and "everyday" spheres of activities (see Lave, 1988 for an anthropological perspective). Research under the label "everyday" has been debated across many disciplines. For instance, recently there was a debate in the study of "everyday" memory (see *American Psychologist*, September, 1989; January, 1991). Banaji and Crowder (1989) argued that studying everyday memory prevented generalizable data and pointed out that "no new principles of memory has been discovered" (p. 1185). Several counter examples appeared subsequently; Ulric Neisser (1991) reported from research evidence that the study of everyday events with young children has helped explain childhood amnesia. More importantly, the study of "everyday" memory has enhanced the understanding of human memory.
translated their solutions into the required classroom form. This provides another distinction between "real" and "other" math. Lave argues that the problems that engage students in this math classroom are dilemmas about their performance and not mathematical dilemmas. This provides shape to their everyday mathematical practice which only gives an appearance of understanding, but does not resemble the everyday practice of mathematicians. Lave (1990) then suggests that to establish mathematical dilemmas in the math classrooms, the dilemmas that are not mathematical must be reduced and the curriculum must create "opportunities for practice" rather than "specification of practice" (p. 324). This would be similar to the learning curriculum found in apprenticeship.

From their research on mathematics in schools, Lave, Smith, and Butler (1988) point out that an "analysis of schooling that does not treat [mathematics] as everyday activity misses its essential character" (p. 68). They recommend further investigation of the classroom as a situated production of everyday activity, because the analyses of these everyday activities—whatever they may be—will provide us with understanding of what is being learned and how it is being learned. This investigation in classrooms might suggest effective ways to improve curriculum practice as well as revise our assumptions of what constitutes everyday practice in classrooms. "[W]hat children engage in day by day in school is everyday practice" (Lave, 1990, p. 318).

Suzanne Damarin (1993, p. 29) suggests, and rightfully so, that a student in a classroom may be thought of as not a single knower with a single body of knowledge which can be constructed in and applied to in diverse
situations; instead, the student is a “confederation of many knowers, each
with its own knowledge.” So, when the student travels from one situation to
another, s/he becomes a different knower and draws upon the knowledge
necessary for the new situation. Understanding this everyday situated
aspect of knowledge directs us to rethink about our notion about cognition.
Earlier it was pointed out that cognition entails all thought processes (Eisner,
1985), but the situated nature of cognition was not discussed. Rogoff (1982),
using L. S. Vygotsky’s view of cognition, suggests that the thought process is
intricately connected with the context of the problem; this context “includes
the problem’s physical and conceptual structure as well as the purpose of
the activity and the social milieu in which it is embedded” (Rogoff, 1984, p.
2). So, without examining the interaction of the participant and the context of
the activity our understanding of an individual’s cognition will be incomplete.
And such an examination will only facilitate the understanding of
“confederation of many knowers” in a student in the classroom. Learning
and cognition are, then, integral and inseparable aspects of generative
social practice (Lave and Wenger, 1991, p. 31). From this view, it can be
said that the classroom itself is socially constituted and the generation of
knowledge takes place through dialectical relations (not linear) between the
student engaged in the activity and the classroom. Cognition in everyday
practice, then, may be thought of as “distributed—stretched over, not divided
among—mind, body, activity and culturally organized settings” (Lave, 1988,
p. 1). Scribner (1986) argues that the nature of practical thinking—that is,
thinking embedded in purposive activities—in daily life must be analyzed
within activities and not cut off from them. “To achieve such analysis, the
investigator needs to select as her object of analysis not an isolated mental process or task in itself but an integral action directed toward some specificable end and accomplished under specificable circumstances" (p. 16).

From the previous section on visualization in classrooms and from our discussion thus far, it can be argued that the process of visualization—the how of visualizing—depends on the interaction between the participant and the context of the activity. The participant is a "confederation of many knowers" here and so it is worthwhile to examine what the participant counts as visualization, how visualization is accomplished, where and when it occurs and so forth. This may provide us with an understanding of what constitutes visualization practice in the classrooms. Moreover, we may find how instructions organize visualizing in various classroom contexts, and what might be the nature of practices in classrooms that nurture children's visualization process. For instance, Rogoff's (1991) research explores how guided participation with skilled partners can support the development of spatial planning skills for young children. Rogoff's (1990; 1991) concept of guided participation, based on Vygotsky's concept of the "zone of proximal development" (which can be simply defined as the distance between what a child can do by working alone and what a child can do when assisted by skilled adults), suggests that both guidance and participation are essential to children's apprenticeship in thinking.

5 Research on reading in classroom life suggests that what counts as reading cannot be defined a priori; instead, reading must be seen as "situationally defined and socially produced in classroom events" (Green and Meyer, 1988, p. 141). This work suggests that to consider reading simply as a "within the head" phenomenon limits our understanding of the everyday nature of reading (p. 157). A similar argument can be made for the process of visualization in the classrooms everyday.
What kind of learning-in-practice supports the process of visualization in the classrooms? Gearhart and Newman (1980), for instance, studied nursery school children drawing and learning how to draw in a context and report that "what children know about drawing is intimately tied to what they understand of drawing activities undertaken in a particular social context" (p. 183). These drawings (representations) are created by the children through interactions in the classroom. Ferguson (1992) suggests that despite the low status of visual thought process in schools today everyday visual thinking "is an intrinsic and inseparable part of engineering" (p. 47). Ferguson points out that engineers use three kinds of sketches to assist in visualization (cf., p. 96-97): thinking sketch (used by engineers to focus and guide their nonverbal thinking), prescriptive sketch (made by engineers to direct drafters for making finished drawings), and talking sketch (created through discussions with everyone involved since everyone spontaneously draws sketches with and to each other). In a classroom, the participants engage in the process of visualization through such sketches; these sketches may be gestural, pictorial, written, or spoken.

John Hortin (1983, p. 20-21) reports that when students are told to think aloud while problem solving, the students verbalize, visualize, act out a situation, and so on. The students experience all sorts of imagery—visual, aural, kinetic, olfactory, gustatory, and haptic. This process of experiencing the image in a classroom includes the internal representations (created in students' minds) and external representations (shared with others in the class). In a classroom, the process of visualization that is achieved becomes visible only through these interactions. In a study of visualization, then, it is
worthwhile to explore how the visualization process is embedded in everyday classroom activities.

Summary

To review the research on visualization, this chapter first presented a brief background on visual imagery, spatial development, gender and visualization, testing and training in visualization, visualization in classrooms, and visual thinking through visual arts. This review suggested a need for examination of the process of visualization embedded in the classroom activities. Such an investigation might provide the knowledge of how teachers incorporate visualization skills in teaching of the subject matters as well as what students and teachers consider as visualizations in the classrooms. A perspective for everyday visualization study in the classroom was discussed. Issues regarding schooling and everyday practice by Resnick, Lave, and others are presented to show that everyday classroom activity is appropriate for understanding the nature of the visualization process.
Chapter III

METHODOLOGY

My purpose was to explore, describe, and understand the phenomena of everyday visualization in elementary classrooms. To attain this goal, I had to study these phenomena in their natural setting so that I could focus on the nature of interaction and intersubjectivity between the classroom teacher and the students and among the students themselves. This was possible with qualitative inquiry which has no predetermined hypotheses and often uses an inductive analysis (Patton, 1990). Such an inquiry differs from the prespecified nature of the quantitative inquiry which suggests the use of standardized measuring instruments to understand the phenomena under study and usually tends to ignore the contextual nature of this understanding (Peshkin, 1988b; Patton, 1990). Eisner (1991) provides six characteristics of qualitative methodology (p. 32-39): (a) qualitative studies tend to field focused, (b) in qualitative study the self is an instrument, (c) qualitative studies are interpretive in nature, (d) qualitative studies make use of expressive language, (e) qualitative studies devote their attention to
particular situations, and (f) the success of qualitative studies is judged on their coherence, insight, and instrumental utility (usefulness).6

In this study I used participant observation as one of my major sources of data. Participant observation is a dialectic process because it occurs, in part, as the interaction of the participant in and with context of the activity. Becker and Geer (1957, p. 28) highlight the importance of participant observation by saying that:

The most complete form of sociological datum, after all, is the form in which the participant observer gathers it: An observation of some social event, the events which precede and follow it, and explanations of its meaning by participants and spectators, before, during, and after its occurrence. Such a datum gives us more information about the event under study than data gathered by any other sociological method. Participant observation can thus provide us with a yardstick against which to measure the completeness of data gathered in many ways, a model which can serve to let us know what orders of information escape us when we use other methods.

Participant observation may be thought of as a combination of field observing and note taking, informal interviewing, audio-video records, and school documents. Using such wide variety of data collection methods, the researcher is able to obtain a wealth of information and, thus, is able to make meaningful constructs of the everyday activities that occur in the

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6 Eisner points that in a qualitative inquiry researcher's judgment is important as it does not rely on standardization. By this he means "seeing things in a way that satisfies, or is useful for the purposes we embrace" (p. 39). Using the self as an instrument, the researcher is able to perceive and interpret the situations directly while taking into consideration her/his own subjectivity (Peshkin, 1988a). The researcher should also be aware of the fact that her/his interpretation of situations (e.g., classroom observations) are "never incontestable" in that there will always be "alternative knowledge communities" who also seek to create their own knowledge of that local level (Eisner, 1991, p. 86; Taylor and Swartz, 1991, p. 60-61).
classroom. For example, "observations provide a check on what is reported in interviews; interviews on the other hand, permit the observer to go beyond external behavior to explore the internal states of persons who have been observed" (Patton, 1990, p. 245). Michael Patton (1990) lists the following advantages of observational data (p. 203-205):

- By direct observation the researcher understands the context of the activities so that she/he may obtain a more holistic perspective.
- By having a firsthand experience, the researcher becomes more "open discovery oriented, and inductive in approach."
- The researcher is able to "see" things in the setting with different perspectives.
- The researcher is able to present the perceptions of the participants as well as of herself/himself.
- The researcher uses her/his personal knowledge and direct experience(s) as a resource to aid in interpretation and in understanding of the activities in the classroom.

For doing participant observation in the classrooms to study everyday visualization, I used an ethnographic approach as suggested by Zaharlick and Green (1991, p. 208). This approach, in part, recommends that the researcher not have predetermined criteria of whatever he or she is studying. So although I had reviewed the visualization literature, I did not undertake my research in the classrooms with a preset definition of visualization. Instead, I was interested in instances which were claimed to be visualizations by my participants and how these are accomplished within and across everyday classroom activities. Such data provided me with the
understanding of what is involved as the process of visualization in the classrooms. The research questions which guided this study were:

- What are the everyday activities that rely upon the development of visualization abilities among students?
- How do teachers incorporate, if at all, visualization strategies in their teaching, classroom activities, classroom interactions?
- To what extent does the teacher rely upon her/his students' visualization skills? How does he/she motivate those who do not have such skills, or provide encouragement to those who need help to get started in using such skills?

Current theories of situated cognition suggest that "all learning is learning in situ" (Suchman, 1993, p. 72; Lave, 1988, 1990; Brown, Collins, and Duguid, 1989a). Classroom instruction not only "situates information" for the learners (cf. Harley, 1993, p. 47) but also guides the practical course of action. Damarin (1993) applied the analogy of travelling to situated knowledge and is suggesting that "we [must] think of a student, not as a single knower with a single body of knowledge which is constructed from and applied in diverse situations, but rather as a confederation of many knowers, each with its own knowledge; as the student travels from one situation to another she becomes a different knower, drawing on the knowledge appropriate to the new situation" (p. 29). To understand how visualization occurs in everyday classroom situations where the students and teachers continually travel from one instructional context to another
drawing on their local (situated) knowledge base, it is necessary to study the kind of tasks (or activities) that occur in the classrooms.

Research setting

My research setting was an elementary school in Columbus, Ohio. The school selected has a unique teaching and learning approach in which the Arts are considered to be an integral component of the school curriculum (see Appendix A; also see Chapter 4 for description of the school). The school opened in September 1982. Its 16 classroom teachers serve kindergarten through fifth grade. Each grade has three class sections and each class has approximately 25 students. Since student assignment to the school is by a lottery system, there are almost equal number of boys and girls in all classes. There are teachers for different Art strands: Dance, Drama, Music, and Visual Arts. The arts team works with the classroom teachers for planning the curriculum. The school also makes frequent arrangements for local artists to come to perform for the children and the teachers.

Participants

Since I was interested in studying everyday visualization in the classrooms, I worked with teachers whom I considered information-rich cases as well as with whom I could build an interactive understanding. My sampling, then, was of the purposeful type (Patton, 1990, p. 169). My research focus was on the occurrence of visualization in classroom situations so there was no sampling necessary to focus on individual
students. I followed the guidelines of the Behavioral and Social Sciences Human Subjects Review Committee at the Ohio State University to get consent for doing this study (see Appendix B). I did not interact with the students whose parent(s) declined their participation in this study.

I had visited the school six times in February 1992 to do a preliminary study to help me frame my dissertation study. This provided me with understanding of some conceptualizations of everyday visualization phenomena on which I needed to focus. Such a process is recommended for it guides the researcher with the information of "what data need to be collected, what collection strategies and tools are most appropriate, what roles and relationships are appropriate for the researcher in the particular situation, and what analysis procedures will yield the desired information" (Zaharlick and Green, 1991, p. 219). I found that the teachers used several visualization techniques in teaching subjects such as reading, math, science, and visual arts (Thakkar, 1992).\footnote{The following observation from Ms. Trudy Parker’s (TP) fourth grade classroom illustrates an instance of everyday visualization in classroom.}

The students were working on a rock identification exercise. [Later, TP pointed out that they were preparing for the next class reading on rocks and minerals.] The students were to close their eyes and describe the shape, surface, smell, and color characteristics of the rocks. Stacy, who was sitting next to where I was standing, when asked to identify her rock said: "it [the rock] is round. It is rough [curvy] on one side, and smooth on the other side. It smells like sewage and it is gray [in color]." After she identified the rock, TP asked her to read the number of the rock which was stuck on one side of it. The rock was identified as being sandstone by TP. It was interesting to note that all children wanted to play this identification game.

TP’s instructions organized the pattern of actions in the classroom. Stacy used her sense of smell to describe the rock. Stacy later told me that she associated the sewage smell with grayness. I noticed that Stacy was feeling (touching) the rock as she described it. Feeling and smelling were contributing to the meaning-making of the rock’s identity which was later identified by TP.
I shared my, then evolving, research design and the preliminary analysis with the school principal, two fourth grade teachers, one fifth grade teacher, and the visual arts teacher all of whom showed interest in my study and invited me back to their classrooms to conduct my dissertation research. I also got along very well with the students since I became a member of the Lizard Lovers club and the Chess club (see Chapter 4). Through the club memberships I was not a "stranger any more" to these students (cf. Schutz, 1976, p. 105). Since my research site is an alternative elementary school, the students and teachers are used to having visitors and researchers in the classrooms.

Data collection

The data collection techniques of my dissertation research have evolved from my preliminary study. In that study I visited the school once a week for six weeks. I realized that for substantial findings I needed larger blocks of time in classrooms as well as a variety of data collection techniques. So, my participant observation was planned to be prolonged and persistent so that I could obtain a "rich experiential context" of the classroom situations (Becker and Geer, 1957, p. 32).

For the present study, I was a participant observer in the classrooms for three days per week from early October 1992 to late January 1993. I participated in the science, social studies, and visual arts periods of one fifth grade classroom and in the math, reading, and science periods of two fourth grade classrooms. I also regularly participated in the chess club meetings. After my data gathering period was over, I continued to make occasional
visits to the school to share my data and to get clarification from the teachers and students. I worked closely with my participants not only to make them aware of my study but also to provide a mutual negotiation and renegotiation of experiences between my participants and myself (Lather, 1986a). The confidentiality of my participants was considered at all times. My main data collection techniques included field notes, audio-video recordings, classroom documents, and informal interviews.

I was introduced to the students in the classrooms by their teachers on my first visit to the school for my dissertation research. I was primarily an onlooker in the classroom during the first two weeks, and as the study time progressed I gradually developed into a participant depending on the context of the activities in the classroom (Patton, 1990, p. 206). I also acted as the teacher’s helper whenever I was at the school.

I gathered audio-video recordings of specific classroom situations after getting the permission of the participants; for this, I used the school's handheld video camera for recordings. These recordings facilitated the recording of the classroom situations as well as allowing for inspection and elicitation purposes by my research advisors, my participants, and myself (Evertson and Green, 1986). Lucy Suchman (1987/1990) states two reasons for studying situations: "One objective in studying situated action is to consider just those fleeting circumstances that our interpretations of action systematically rely upon, but which our actions routinely ignore. A second objective is to make the relation between interpretations of action and action's circumstance our subject matter" (p. 109-110). So, these recordings allowed me to capture situated actions in the classrooms.
Observations in the classrooms lead on to conversations with the participants to either provide detailed information or to clarify my reading of a given situation. In my preliminary study, I was unable to get any formal interviews with the teachers and students due to their hectic schedules during the school hours. I realized then that informal interviews during the school hours (such as during silent reading and lunch time) were of great convenience to my participants. Lather (1986a) argues that interviews when "conducted in an interactive, dialogic manner" can bring about a greater mutual understanding between the researched and the researcher (p. 266).

As I gathered my data on everyday visualization in classrooms, I kept in mind this suggestion by Eike Gebhardt: "what we want to collect data for decides what data we collect; if we collect under the hypothesis that a different reality is possible, we will focus on the changeable, marginal, deviant aspects ... all the "facts" unfit to fit" (cited in Lather, 1988, p. 576). Denise Farran (1990) argues "how 'data collection' is effectively 'data construction'" (p. 91). She suggests that contextual information is required to make sense of the data that is collected; for example, statistics are a construction of reality and usually they "are divorced from the context of their construction and thus lose the meanings they had for the people involved" (p. 101).

**Data analysis**

Elliot Mishler (1979) advises that meaning is contextually grounded, and so the understanding the context of the situation is necessary for the interpretation of that situation. Gail McCutcheon (1981) argues that
"interpretations render our observations intelligible by relating events to one another and by providing a conceptual context in which place to observations" (p. 5). McCutcheon (1981, p. 6-7) describes three types of interpretations for classroom observations: (a) forming of patterns in the classroom. The participants, often, are unaware of their behavior; at times, such behavior is unconsciously patterned, (b) interpretations of social meanings of the events and situations through "thick description," and (c) interpreting classroom phenomena in relation to the external considerations—theories, trends, history, and other relevant contexts. Each type of interpretation provides a different perspective on classroom observation.

The analysis of the data did not wait until after all the data had been collected, but rather it was on-going with the data gathering period. I inferred themes and categories from the data to make sense of the everyday visualization in the classrooms. My data were gathered in forms of audio and video tapes, field notes, and classroom documents.

Analysis of the video tapes was done in three phases. In the first phase, a backup of the original tape was made immediately after returning from the school. Then a rough content log was made from the backup. A log described key events related to the phenomena under study by indexing these events with frame counter and time (e.g., Suchman and Trigg, 1991, p. 77). Events were indexed as remarks on the log; remarks made note of verbal, gestural, and pictorial interactions. These rough logs were helpful later in identifying instances of classroom instructions that I wanted to focus on. Notes from participant observation in the classrooms as well as
classroom documents were filed along with the rough logs for completeness sake.

In the second phase, instances of the recorded classroom events were selected for repeated viewing. These selected instances (collections) were viewed, when possible, by my research advisors and my teacher participants for discussion purposes. Based on these selected instances, the participants were interviewed informally and audio taped. Their reflective comments were then transcribed. It was not always possible to show such instances to my student participants. The criteria for selecting instances included my interest in the classroom phenomena under the theme of everyday visualization and the intelligibility of the sound recorded on the video tape.

Ann Brown (1992) suggests that the researcher must convey that which is "not only selective and not representative, but also the more important general, reliable, and repeatable" (p. 173). Keeping Brown's advice in mind, I identified instances from video tapes for detailed transcriptions noting down both verbal and nonverbal communications of my participants. I also used my notes from participant observation, informal interviews, and classroom documents for making an extensive understanding of these instances. The detailed data analysis started in the third phase after my data collection period had ended. For example, I had video taped six chess sessions (around 5-10 minutes per session), and I focused mainly on three sessions.
Validity

Validity is not an inherent property of a particular method, but pertains to the data, accounts, or conclusions reached using that method in a particular context for a particular purpose. (Maxwell, 1992, p. 284)

I worked closely with my participants (especially with the teachers) during the data collection and data analysis periods. This, however, is not some kind of respondent validation but more of a reflexive elaboration, because my interpretation is also an interpretation, and the disagreement or agreement on part of my participants "of this interpretation does not reduce or enhance its credibility or trustworthiness" (cf. Sparkes, 1989, p. 143). McCutcheon (1992) considers the discussions with research participants about the meaning the participants make of the research topic and data that is collected/analyzed as "constructivist" member checks.

Unlike in a quantitative inquiry where the credibility of the research is addressed through standardized measures, in this qualitative inquiry credibility is established by following the guidelines offered by Lather (1986a; 1986b) to guard against researcher biases: (a) triangulation, (b) face validity, (c) catalytic validity, and (d) construct validity. Triangulation includes the use of multiple data sources, methodologies, and perspectives. The use of multiple methods for data gathering (audio-video recordings, participant observation, and informal interviews) and the sharing of the data and on-going evidence with my participants and research advisors established triangulation of data sources for this study. To ensure face validity, I recycled evolving descriptions and analysis which I may have
tentatively formatted to the participants. Throughout my research (preliminary and dissertation) period, I have shared all of my written work related to visualization with the teachers involved in the study. However, I was unable to do any of these member checks on my on-going written descriptions and analysis with the student participants.

Lather (1986a) is concerned with empowering the researcher and the researched for building a praxis-oriented research. Her conceptualization of catalytic validity refers to the phase where the research process “reorients, focuses, and energizes participants toward knowing reality in order to transform it” (p. 272). In this research, however, I worked together with my participants so that they could gain an understanding of my research (dissertation process), of the visualization processes, and of themselves as visualizers. This also allowed the teacher participants to understand their own practices better as well as understand the role of visualization in learning. Lather’s construct validity suggests that research “must operate within a conscious of theory-building” (p. 271). I am interested in what counts as visualization in the classroom for my participants. The activities in these classrooms were shaped by the teaching practices of the teachers (such as making an illustration of short circuit on the board in the science period, encouraging students to discover different shapes in math period, and allowing students to externalize their thoughts in the visual arts period). This study, then, provided me with a different perspective on the visualization processes than that which is traditionally defined by the psychometric studies.
Patton (1990, p. 472) has suggested that qualitative inquiry should also address the issue of the credibility of the researcher in terms of experience, training, and perspective. Here I address this issue. I was familiar with the psychometric studies on visualization research and, indeed, based on review of this research I wrote a tentative research proposal on visual-spatial training for preservice teachers; an earlier version of this was submitted as a part of the course requirement for a quantitative research methods course. Professor Damarin and Professor Belland, my graduate committee members, then advised me to do undertake field study in elementary classrooms to understand the ways in which visualization is important to students and teachers. Their suggestions and my further readings led me to do a study on everyday visualization in the elementary classrooms (see Chapter 2). As part of my training to undertake this qualitative study, I had to take two further courses in qualitative research methods offered by the department faculty. I had already taken one qualitative course where I had made an initial contact with the elementary school. I worked on my preliminary study in the second and third courses. I have shared my ongoing writings with my advisors and teacher participants (often including the school principal) to demonstrate my credibility as a researcher. I also did get funding from the Graduate School to help pay for the data collection expenses of my research.

Qualitative studies are also concerned about generalizability. However, when a study concerns an educational setting we must realize that all knowledge is context-dependent. "Generalizations in education ... need to be treated as tentative guides, as ideas to be considered, not as
prescriptions to follow" (Eisner, 1991, p. 209). Since generalizability is often thought of as independent of the context, Patton (1990) suggests "extrapolation" of study findings (Cronbach et al. cited in p. 489). "Extrapolations are modest speculations on the likely applicability of findings to other situations under similar, but not identical, conditions" (p. 489). The findings of this study, which are setting specific, describe the visualization processes in everyday classroom activities. The instructional implications in Chapter 5 are suggestions based on these study findings.
Chapter IV

PRESENTATION OF THE STUDY DATA

The data presented in this chapter are gathered through participant observation, informal interviews, and audio-video recordings of the student and teacher participants in one fifth grade classroom and two fourth grade classrooms of an elementary school. My purpose was to explore, describe, and understand the phenomena of everyday visualization in these classrooms. So, I studied how the process of visualization was embedded in everyday classroom activities. To achieve my purpose I was guided by the following three general research questions:

- What are the everyday activities that rely upon the development of visualization abilities among students?
- How do teachers incorporate, if at all, visualization strategies in their teaching, classroom activities, classroom interactions?
- To what extent does the teacher rely upon her/his students' visualization skills? How does he/she motivate those who do not have such skills, or provide encouragement to those who need help to get started in using such skills?
These questions allowed me to examine the work of visualization in these classrooms. I gathered data in different subject areas. I address these general research questions through descriptions of my data in different subject areas. Through these descriptions I demonstrate that everyday visualization is about the participant's action—her/his interactions with the environment—situated in the classroom context. But, first I provide a description of the school.

**School program**

My research setting is an Arts IMPACT (Interdisciplinary Model Program in the Arts for Children and Teachers) alternative elementary school. "Arts IMPACT is a teaching/learning approach in which the Arts are infused deeply into the basic academic curriculum" (see Appendix A). The teachers of different Art strands—Dance, Drama, Music, and Visual Arts—work together with the classroom teachers of all grades for planning the curriculum. Once every month there is a teacher/Arts team planning session where the classroom teachers share their themes in various subject areas with the Arts team. The Arts team provides input on how the arts can enhance the teacher's subject objectives. For example, Ms. Trudy Parker's mathematics theme in January 1993 was geometry. Ms. Parker, the classroom teacher for one fourth grade class, worked with Ms. Mona Ball, the school's visual arts teacher, to obtain appropriate resources so that Ms. Parker's students could learn about the lines and patterns of the Nasca Indians of southern Peru (see section "You need lines in almost everything you do", page 149). This matched Ms. Parker's social studies theme where
the students were learning about the customs and traditions of many Indian tribes of the Americas (North, South, and Central). During the Arts periods, the classroom teachers are also encouraged to participate in the activities with their students. For example, Mr. Peter Hart, the classroom teacher for one fifth grade class, participated during a visual arts lesson on Salvador Dali (see section Looking and seeing in the art room, page 81).

The school's handbook suggests that the mission of the school is “to provide the finest elementary education through the Arts IMPACT process.” All over the school there are displays of students' works such as paintings, poems, and models. Students are assessed individually on their participation in the arts: extra participation, participation, and minimal participation. The progress reports are sent to the parents during the school year. Students also share their work with others through class and club performances. Local artists in Columbus are also invited to perform at the school. These school performances are held to encourage students to develop their creative selves personally and through collaboration with other students and teachers within the framework of the class curriculum. The school has all sorts of clubs such as the Lizard Lovers club (see section "Neeble, Neeble", page 60), the Chess Club, and the Drama Club.

School schedule

The school year is divided into two terms. The first semester started on September 2, 1992 and ended on January 22, 1993. The second semester started on January 25, 1993 and ended on June 11, 1993. Classes start everyday at 9:00 a.m. and the students are dismissed at 3:30 p.m. There is a
lunch period from 11:45 a.m. to 12:45 a.m. and a short recess from 2:15 p.m. to 2:30 p.m.

Classroom teachers set their own daily schedules for teaching different subject areas depending on the Arts schedule. The classroom teachers are required to cover the subject objectives provided by the Columbus Public Schools. For instance, Mr. Hart gave a short review on diagramming sentences (a required topic) to his class since he had some time left before a social studies period. Sometimes the day begins with a circle meeting where the students show and tell and discuss issues. Weeks before the presidential elections, for instance, the students in one fourth grade class shared editorial cartoons with each other in a circle meeting. A poll was conducted and the class picked Governor Bill Clinton as the next US President. Because the classroom teachers have to set their schedules from the time left over from the Arts periods, they have to juggle their classroom schedules. Mr. Hart, for instance, started a unit on electricity in science on October 8, 1992. He gave a second lecture the next day, but the third lecture was on October 14. Since his class had Arts all morning on October 10 and 11, there were no science periods on those days.

School principal and classroom teachers

Dr. William Dow (WD), the school principal, embodies the philosophy of the school. He has travelled to many Asian countries and supports international activities in the school through the arts. He has a doctorate in education from Iowa and he is an ardent Hawkeye fan. Outside his office a large poster says: It Is Okay To Be YOU! I have seen him come to
classrooms where I have been present and I noticed that the students would talk to him with great ease. WD encouraged me to conduct my research in the school and gave me permission to use the school's video camera for my recording purposes.

I was invited by Mr. Peter Hart (PH) to his fifth grade classroom. PH has been teaching in this school ever since it opened. He has a Bachelor of Science Degree from the Bowling Green State University and also a Master's Degree in Divinity. He has previously taught for five years from kindergarten to eighth grade and another five years in middle school. I have gathered data in science, social studies, and visual arts periods from PH's classroom. I also gathered data from the school's chess club of which PH is the advisor.

Ms. Trudy Parker (TP) and Ms. Trisha Miller (TM) invited me to their fourth grade classrooms. TP has been teaching in this school for last six years. She received her Master's Degree in Reading from the Ohio State University. TM has been teaching in this school for past two years. She has a Master's Degree in Education from the Ohio State University. From TP's classroom, I have gathered data in mathematics and reading periods. From TM's classroom, I have gathered data in science periods. Because of the way the Arts schedule was made in the first semester for the fourth grade classrooms, I did not get to spend a lot of time in the classrooms of TM and TP as much as I did in PH's classroom. Furthermore, PH was able to let me know his subject schedules a day or two in advance while TP and TM made their schedules on a day by day basis. PH also seem to be involved with many school activities; for instance, he regularly participates with the lizard
lovers club. I give a short description of this club before introducing my data descriptions.

"Neeble, Neeble"

Neeble, Neeble. How are you?
I am fine. How do you do?
I'm in shape, how 'bout you bod?
Eeek, egads you are a pod!
Don't be scared. I am not a thud.
I want to join the Lizard Club.
Well, I suppose that you can.
But first, I'll check with Uncle Dan.

Reynold Dadismann
[5th grade student]

"Lizard Lovers" is a literary club in the school. Lizards are very creative and they love to read books by Daniel Manus Pinkwater [Uncle Dan]. To become a lizard, a person must first read Pinkwater's *Lizard Music* and then pass a simple test based on this book. The club meets twice a month on Thursdays during lunch periods. The lizards use Neebleninn as their language and the word neeble seems to be the only word in their language. Neeble can mean anything depending on what the lizard is trying to say and how. Students who are not lizards are referred to as "pods." A pod is ignorant of the lizard way of life. Lizards use terms such as "very lizardry" and "unpodlike." A student assumes a lizard name before taking the oath of allegiance to the lizard way of life. All lizards must carry the club card. Female lizards usually call themselves Helena while male lizards call

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8 A real lizard would not write this account. Lizards do not follow traditional ways of doing anything.
themselves Raymond or Reynold. There aren't many lizard names so often female lizards pick male lizard names. Jean, for instance, is Reynold. [She is the author of the poem which is in the beginning of this section.] My name is Raymond. I became a member because I wanted to know fourth and fifth grade students and I also became interested in lizards after I read the Pinkwater book.

Being a lizard allows students to be more creative and imaginative. Pods, on the other hand, are considered by lizards as those who have no imagination. Mimi told me that it was funny being a lizard and "if you don't know what to say, say neeble" [12-14-92]. One Thursday all around the school there were notices which asked the lizards to bring an orange splot to the meeting. The notice also said that pods were not welcomed. The lizards read *The Big Orange Splot* by Pinkwater and shared with each other their orange splots. A typical orange splot was a big orange mark on a white piece of paper, but it could be anything. Lizards try to be creative by doing and saying unusual things. For instance, Helena [Mimi] who was running to be an officer of Lizard Lovers gave an interesting speech [emphasis in the original]. She was, of course, elected.

My fellow Lizard Lovers,

Neeble neeble neeble and yet neeble neeble neeble but still Neeble Neeble Neeble Neeble!

So let's have the most unpodish lizardsary! Give the club a tail. Vote for someone who has legible writing, has a very unneeble (unforgettable) mind and of course! she/he must know how to neeble or else.

So before you neeble your (hopefully) unpodish vote think about it! A Turner lizard needs to fill in the lizardsary's spot! And may I add I am a very good neebler.

Vote Helena Turner for Lizardsary!
Don't be a pod
No
Don't be a pod
(In other words vote for me, neebie for now.)

Reynold [PH] encourages all lizards to have fun during the club meeting. Lizards enjoy reading Pinkwater books or writing lardy poems. Students learn to take interest in books and try to be imaginative.

**Introduction to the data descriptions**

Data transcripts and descriptions presented here are from the school chess club, fifth grade periods in visual arts, science, social studies, and diagramming sentences, and fourth grade periods in mathematics, reading, and science. The data descriptions are presented in following seven sections: 1) Learning to see in the chess club, 2) Looking and seeing in the art room, 3) Using illustrations on the board for teaching science, 4) Diagramming sentences, 5) Role-playing in social studies, 6) Ways of knowing cubes, pyramids, and lines, and 7) Mystery powders. Each section ends with a summary paragraph. After presenting these data descriptions, a discussion on the process of visualization in these classrooms is provided.

The following notations are used in the transcripts:

- ( ) Words in parenthesis indicate what the words might have sounded like.
- (...) This parenthesis refers to an inaudible utterance or utterance not related to the lesson.
- [...] This bracket refers to the text that is not included.
- *italics* Words in italics are of our main interest.
The data were gathered between early October 1992 to late January 1993. The recordings were made after getting the permission of the teacher and student participants. The video camera was hand-held by me in the back of the room in most classrooms. This allowed me to direct the camera around the classroom. I sometimes connected an external microphone system to this camera and placed it in the center of the classroom.
LEARNING TO SEE IN THE CHESS CLUB

The November 4, 1992 edition of the school newspaper reported that the school's chess club, the Pawns from the Dungeon, had defeated the Rampaging Rooks of the Columbus Academy. This is a common news story of the school's chess club. Mr. Peter Hart (PH) is in charge of this chess club. The club meets every Wednesday during the lunch period in the drama room. There is a short chess lesson in the beginning of every club meeting which PH conducts. The club members then play chess among themselves using notation sheets and time clocks. The chess club members are students from all grades, first through fifth.

PH: These lessons even though they are only 5 minutes long, once you start to see these things, you are going to start to apply [them] in to your games. And you are going to learn a lot faster than most adults learn. And it is not very much of your time, but for those of you who pay attention, you are really going to start to connect and begin to see things that other players will never see. Some are real easy; some are real hard. I have a book and you can buy books that have these situations. It is called tactics. Most of you know how to move the early openings pretty successfully. But, the difference between your winning and losing is whether you can see what to do in a certain situation. That's why I am giving you these lessons. To show you what brilliant players can do in situations and win games. And when you start pulling these stunts, you are going to start winning games. [12-9-92]

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9 I made six video recordings of these chess lessons. I also made a few audio recordings of my informal conversations with the club members.
All students who are part of the chess club go through the basics in chess playing such as the need to develop knights and bishops early in the game. PH also provides lessons on pins, forks, skewers, and discovered attacks. Students get handouts on these lessons. Students also witness chess puzzles on an illustration board during lessons. The skill in chess playing grows with practice, and in these meetings students begin to collect experiential knowledge and skills necessary to “see” things on the board. The students are guided through interactions on what to look for and what to see on the board so that they can win games. As the lessons continue PH gets more and more complicated so that the students “can visualize more of the game and visualize more moves ahead” [1-27-93]. The objective of PH in these lessons, as evident from (1), is to instruct the students in ways of seeing the chess board.

**Visualization in the chess club**

PH frequently tells the students to “see the move in your mind.” Often he would tell them to “visualize the chess board and use your imagination.” I once asked PH what he means (to the students) when he uses words such as “imagination,” “visualize,” or “see the move in your mind.”

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10 Chase and Simon (1973) suggest that the mind’s eye in chess may provide spatial and physical relations of the pieces on the board which allows the chess master to “see” meaningful yet unfamiliar patterns which are not so evident to the novice player. Here, the mind’s eye is not disengaged from the chess pieces as it will be evident from these data, but is at the center of all sensory interactions between the objects (pieces) and the subjects (members).

Yakimanskaya (1991) suggests that spatial thinking is a type of representational thinking since representational thinking deals with visual, auditory, and kinesthetic images (p. 72-74). Also, to develop spatial sense children must be provided “experiences that focus on geometric relationships; the direction, orientation, and perspectives of objects in space” (National Council of Teachers of Mathematics (NCTM) Commission document cited in Yackel...
PH here presents the issue of everyday visualization: "it's hard to know what goes on in the mind." We also find PH's instructional intent—to see a move is to find its meaning. PH, while acknowledging the difficulty of knowing what goes in his students' minds, frequently uses drawings and words to invoke mental images in his students' minds for understanding the concept he is trying to teach (see section Using illustrations on the board for teaching science, page 95). Of course, the students develop their own images in order to make sense of these concepts.

Matt, a fifth grader, who is considered to be one of the best players in the school told me that while playing chess he imagines "a big castle on a big chess board and all the people are the chess pieces." I asked him how he uses visualization in chess.

If I see a move, I try to visualize in my head instead of using the board because sometimes it helps and makes it easier and you can think better. I have this castle in the middle of the chess board and every time I make a good move they [the people] get moved up and every time I make a bad move they get moved down. So, basically, I try to visualize the move and I take it out and if the piece moves and Wheatley, 1990, p. 52). Spatial abilities can also be developed through motor activity and body movement (Musick cited in Owens, 1990, p. 50).
up I see what other pieces could try to move up and I want to see which one can move up to the highest rank. And I use that. [12-8-92]

For Matt chess, art, and drama work together to influence him in learning. From (3) we know that Matt creates an image of a castle in the middle of the chess board. Also, visualizing the move in his head before moving an actual piece on the board may allow him to see the spatial relationships of the pieces (functional properties of the pieces) and physical relationship of the board (in terms of rank [horizontal row of squares] and file [vertical row of squares]) more clearly. When the lesson was on the endgames I asked Matt how he uses his “castle” in the endgame strategy.

(4) Matt: Well, you see, the castle is like a fence and the king can’t cross the fence and the pawn is like a maybe a little king. They are just like a fence post, if you think, because it can become like a really, really good fence if you can get it all the way to the other side of the board. In the endgame, usually what’s left is maybe a bishop, a king, a rook, and another king and some pawns. So, if you could like somehow, if you could check, or if you could somehow get the bishop on the other [side] to the opponent, you automatically, not automatically, but you very easily have the game won because in effect he [the bishop] is blocking out the king so the fence post can get up to the other side and become a complete fence but more powerful than the other fence. So, working together they could surround the king in fence and make it so he could not get out of the fence and he would have to surrender and lose the game. [2-10-93]

Here, Matt is thinking about the endgame strategy, and the presence of the bishop in his castle suggests the influence of this piece on all parts of the board at once. Although the pawns are less valuable, in the endgame
though they can be like bodyguards or a fence post for his king. Using the bishop and his fence post, Matt is able to defeat his imaginary opponent. His “chess image” of this castle is composed of functional properties of his pieces and pawns as well as their movements on the board (Milojkovic, 1982). For Matt this visualizing (or using imagination) allows him to understand what he is doing, why does he need to do it, and how can he do it. Also, imagination may allow him to “generate” new moves, patterns, and so on (Finke, 1992). Simply seeing and looking disengaged at the chess board is not enough. This shows the weakness of cognitive modeling research which suggests that representations are stored in a person’s memory.11 From (5) we also find how he relates this way of understanding in other areas such as in division.

(5)
Matt: Well, if you just see the board with the pieces that can move and the strategies, then all you have is the board, the pieces, and the strategies and you have no fun. If you use your imagination, you have fun and you are not as nervous so then you become a better player because you would not be so tensed. And using your imagination you can actually see the things, understand them—like in division, my teacher is saying: “okay, you know how to do division, but do you understand what you are doing.” If you use imagination in chess, you can understand what you are doing so you can do it more often and not just because you kinda see it. But, if you use your imagination, you will understand what you are doing and you will understand

11 Clancey and Roschelle (1991) argue against cognitive modeling research claims that representations are stored in a person’s memory and can later be manipulated by reasoning procedures. Instead, representations are products of interactions with the environment. The products of interactions can be sensory, gestural, and interpersonal. So, representations are created through drawings, writings, speaking, visualization, and so on—“a learner participates in the creation of what is to be represented and what constitutes a representation” (p. 5).
why you need to do it and understand how to do that so you will be better off than just seeing what happens. [2-10-93]

Matt also pointed out that he tries to understand the patterns such as those involving checkmates through discovered attacks which PH talks about in the lessons because "if you understand it then you will be able to use the patterns." PH, according to Matt, "lives to see people using the patterns because that means his lessons are working and people are understanding [them]."

Instructions to see in the chess lessons

On October 28, 1992 PH conducted a lesson on skewers. Handouts on this lesson were distributed to all students.

(6)

PH: Listen: "A skewer is explained most easily by comparing it to a pin. In a pin, remember, the attacked piece cannot move because it's shielding a more valuable piece." (...) So, if a knight is in front of a king and you put a rook on that file. He can't move his knight because he'd be in check. That's a pin. Think about the idea. The three pieces are in a line.

"In a skewer, however, the shielding piece is more important and it must move out of the way." Okay, so, you got an important piece being attacked and when it moves out of the way somebody else is hiding in the wings and that's the piece you're going to nail.

"When it does move, the attacking piece captures the other piece." In both the pin and the skewer, we find three pieces in a straight line with each other: the attacking piece, the attacked shielding piece, and the shielded piece."

Now, let's look at the left hand corner. As I read you follow. "Look below at the diagram on the left. The black bishop on b7 is attacking (and checking) the white king."

You all see this I hope.

Students: Yeah.
Adam: Yeah.
PH: "When the white king moves," hmm, the black bishop, Ben, is going to do what?
Ben: (Take the rook.)
PH: Take the rook on h1. Do all of you see it?
Students: (Yeah.) [speaking softly]
PH: Now, folks, this is kind of like a pin. It is three pieces on a line. (....) What you start looking for, if you are a good chess player is when every guy moves his king and queen on the same line or his rook and his queen on the same line or his king or a knight or a bishop on the same line, if you can attack that line, you're going to get rich, either way a pin or a skewer.

Figure 2. Illustration of the board with a skewer.

This (6) is an example of how PH employs seeing as an instructional device, organized through questions/answers, in the chess club. [Note that PH has already given a lesson on pins.] He reviews the principle behind the pins first and relates it to the fact that in a skewer as in a pin, "we find three
pieces in a straight line." The concept of a straight line is no longer abstract here since PH relates it to the projected movements of a rook on imaginary file. But, as PH explains, in a skewer it is the shielding piece which must be moved out of the way. PH leads the students through an example on skewers now. The three pieces—bishop, king, and rook—are in a (diagonally) straight line but this time it is the motion trajectory of a bishop (not of a rook). The purpose of the statement, "You all see this I hope" is not only to get the attention of the members but also to get them to see the spatial relationships among the three pieces. After a response from the students PH directs the question to Ben who gives a correct answer. But, PH whose interest is also to prepare his students to play in tournaments responds with: "Take the rook on h1." This provides students with the rook's physical relation on the board. He ends this example with instructions to look for instances when a opponent moves his king and another piece (such as a rook or a knight) on a same line. The task of the bishop taking the rook on h1 (and of moving the king to f2, f4, e2, or e3) now becomes visible to the students.

On November 18, 1992 PH conducted a chess lesson with an aid of illustration board.

(7) PH: I am going to keep it [illustration board] mostly for one-on-one lessons if I am talking to you or to demonstrate. We are not going to use it to play on—that's not it's purpose. But, everybody in the room can see this. It is a nice board with good visuals. Notice red is used instead of white and that's for obvious reasons if you think about it. White does not have a very good contrast against most colors. [...] I am going to continue to use this board to set up situations from your games, from my games, and games with
computer, to try to help you guys to start to see how to use the strategies that I have taught you: pins, forks, skewers. This is the way you will beat your opponents. Look for them and when you find them: use them and you're going to catch them. [...] This actually came up in the game this week and it is very interesting. I was talking to Matt who was playing with black pieces actually it was white. And, I say [to] Matt his bishop was stuck over here [pointing to empty square f8] and his rook was stuck over here [pointing to empty square h8]. And, I said "get your rooks out here and line up your rooks where they can make an attack" [pointing to file d]. And I was helping him play me. I want you to see what he did. It is now black's move. I traded off here so that this square would be open. [A black pawn took a piece at c6]. My plan was to get over here and checkmate him [pointing to the empty square on b4]. But, he slipped his little queen here when I was not watching very closely. And if you look now, he used a very, very good move. Most of you in the room, unless you have had help will not be able to see it. But, I am going to give you some pointers.

Matt: (I did not help.)
PH: Adam, tell me what piece you are going to move; don't tell me the move.
Adam: The rook on D4.
PH: Okay, yeah, Adam is one who can... (...)
This is a really neat move, folks, and I am going to give you some help. The rook is going to move [pointing to d4] and it is going to threaten the queen [at e1]. That is a pretty strong attack. And when he did this to me, I said to myself, "wait a minute, if he moves down here and attacks my queen, what's my problem? I have one, two rooks and a queen all threatening that rook." But, folks, that's not what he was doing. Look at the board now and see what black's follow up move is.

Carl: (Discovered attack.)
PH: It is a discovered attack.
[There are some Oh's and Ah's in the room]
PH: And if you see what I didn't see. I really did not see this. Matt hit me from the blind side [and PH makes a facial expression].

Class: [Laughter led by Carl]
PH: It is a very good move. What is it, (Carl)?
Carl: Bishop, I mean the queen takes, what's called, b2.
PH: Queen takes b2 is a checkmate. Will all of you look up here? His queen is threatening this piece. When he moved
his rook out of the way [from d4]; this is a discovered attack at it sweetest. A discovered attack: the bishop is not threatening but when he [the rook] moves out of the way; there is now a threat. Double attack. [PH points to the directions of the black's queen and bishop]. I have got to deal with this [points to the rook on d1 and the queen on e1]. If I move this pawn [on b2 to b3], Nate what's going to happen to me now?

Nate: (Check.)
Carl: (Check right there.) [Carl makes a sound]
PH: I am going to lose my queen.
Carl: (And he still got a checkmate.)
PH: He has not got a checkmate now. (...) But I am going to lose my queen. So, really, this move is an excellent move. Because I was not paying any attention, like a dummy I just took his rook. And he bopped in here with his queen and that is the way game finished. Checkmate very nicely done. We will continue to use this [illustration board] for demonstration purposes. I appreciate all of you giving me money towards this cause. Because it is an excellent tool for us to learn to see.

Figure 3. Board configuration of the game between Matt and PH.
In (7) we find several instances of how PH organizes instructions to see the motion trajectories of the pieces on the illustration board. The illustration board is large enough for all the members to be able to see clearly. While the pieces are already in place on the board, PH shows the club members through gestures and verbal interactions how Matt's and PH's pieces came to be where they were. He, then, directs the class to see what Matt did. PH mentions about a piece which he traded off earlier on c6 to act upon his plan to checkmate Matt. But, Matt had placed his "little" queen on b7. But, now with the queen on b7, Matt had a good move. The background on the pieces is given to the club. PH, though, points out that he will provide pointers since most members "will not be able to see" Matt's next move. The students (except Matt) at this point are led to inspect the board now—they are to anticipate the next move. PH has also provided chess tip for newcomers to the club: "line up your rooks where they can make an attack." Through gestures and verbal interactions while using the illustration board PH creates, re-creates representations for the members since he (and Matt) already know the next move. These representations are continually reconstructed by all who are present in the room.

Adam suggests that the next piece to move is the rook on d4. Adam, a third-grader, is the school champion. Now, PH moves the rook to d1 and shows the scenario for a discovered attack which Carl immediately sees: queen takes b2. PH explains the discovered attack to make sure all others also see it. PH gestures at the possible motion trajectories of black's three pieces: rook, bishop and queen. This, he hopes, allows his students "to connect and begin to see" tactics in chess. PH is trying to lead the students
to find the piece since the move can be seen from knowing it. [It is to note, however, that PH did not consider the possibility of the white rook to f8. This would have created a problem for Matt. It is likely that PH may have left out a piece or two on file f for the purposes of this lesson. Nonetheless, it was interesting to find that no one saw this move. Perhaps, PH’s instructions for the class to see what Matt had done did not involve that part of the board; thus, limiting what the members were to see.]

PH often reorganizes chess pieces in these lessons so that his students learn different tactics. On December 9, 1992 he shared an example from a chess magazine. This chess example was from a game played between two grandmasters. Before introducing this game, PH tells students that Carl had used a similar idea against him. PH wants his students to notice the benefits of establishing and developing their pieces early. In (8) he tries to show how four white pieces—queen, rook, and both knights—work together to checkmate the black king.

(8) PH: Notice this diagonal [pointing to the white queen on c2]. Looks like good news, but there is no support piece [pointing to file h]. There is no rook here to support [the queen]. The knight can’t support from here [g6]. Look at couple other things. This knight can go here [e7] and put him [black king] in check. Right? What’s the black [king] going to do? He is going to move over here [h8]. So, that does not help so much. Now, you got a rook over here [a4]. Now, if you get your rook over here [h4], you got a checkmate set up. Right? [See Figure 4.]

Students: (Yeah.) PH: But all black has to do is this. [PH moves pawn from h7 to h6.] Now, the queen and the rook can’t checkmate. So, that’s not going to work. But, with all those things in mind, the guy with red [white]... Now hold your breath folks, this will blow your mind. This is
so brilliant. *Using all three of these ideas in right combination, here's what a brilliant chess player can do.*

First move, queen [c2] takes pawn [h7]. Check.

Matt: (What?) [Chatter in the room]

PH: [...] This is when you put an exclamation point on your score pad with a question mark. Weird move. What is he doing? Because the obvious response... Slow down, guys. If you see it, I am proud of you. I am not going to call on you.

The obvious response is to take—it is the only thing black can do. He can't move out of check. Now, what do you think the next move ought to be?

Jerry: Ah, rook moves to h4.

PH: Now, the rook moves to h4. And this is sweet. This little knight innocently sitting here [e5] guarding this knight [c6] also is guarding this square [g6]. So, the king is forced and there is only one square on the board where he can move. Where is it?

John: Back (there.)

PH: Don't say back there. Tell me?

Carl: [Laughter]

John: g8.

PH: Only g8 is available for the king now.

And now, sport fans, the sweetness of it all. What does he do now to put icing on the cake?

Carl: I know.

Sam: You move the knight to e7.

PH: And you have got a check mate.

And I saw that and I was just about to die. Because, now, the rook is doing his job, and the knight is doing his job, and the king has had it. And it started by throwing your queen right down the tubes.

Carl: [Laughter]

PH: Now, I show you that because the idea is the potential [of the board]. You know like a lot of you guys have a check like this and you say, "oh, goody! oh, goody! I can check." (...) *And you get all excited and you move here [e7] and check the king. What good does it do? None. The king moves over here [h8] and you haven't done anything. This is why you get as many pieces out, establish, develop. Notice how all three pieces are developed and notice he uses one, two, three, four [both white knights, rook, and rook]—all four of his pieces play a part in the check mate. Every piece he has. Now, if this rook [a4] was back here [starting position h1] in the corner some where, it won't do him any good. (...)"
PH leads his students to see these moves through gestures and verbal interactions as he organizes questions/answers. PH shows how moving the white knight to e7 will not accomplish anything as the black king can move to h8. After PH gives his tip of the day ("get as many pieces out, establish, develop") to the class, Jerry demonstrates another sequence of moves for white. Using the illustration board, Jerry shows that a checkmate can be accomplished by just three moves, not four. First he moves knight to e7, then queen to h7, and finally rook to h4. PH, at first, disagrees. Martin yells "it will be quicker." There is chatter in the room. PH finally realizes that Jerry's sequence of moves also works. PH, however, wants to make sure that the students learn the tip of developing the pieces early and having a
plan of attack. He, then, shares the scenario between Carl [white] and himself [black]. He uses the same board configuration while only changing one piece: placing the white rook on h1. This illustrates how PH reorganizes chess pieces in his lessons. Figure 5 shows the board configuration of the game between Carl and PH. Notice that except for a few changes (for instance, on file h) the board is same as shown in Figure 4.

Figure 5. "He had a bishop where the queen is."

(9) PH: The lesson for today, folks, is to plan ahead, have ideas and reasons because you can start pulling this kind of stuff on me. What Carl did to me basically was this idea right here. He had a bishop where the queen is and his bishop came and took this pawn [h7] and checked me. I had to move here [h8] and he moved his bishop out of the way which checks me discovered [directing the path of the
rook on h1]. And his bishop went over and attacked my queen. I could not do a thing about it. [On the illustration board red pieces are used instead of white pieces.]

PH frequently shares his own experiences with the class; often, his purpose is to make his mistakes visible to the students. Here, PH is interested in conveying the importance of taking time to visualize the chess board [1-13-93].

(10)
PH: I am going to tell you one other thing that happened to me just yesterday, last night. And (...) Matt is the guy who is used to listening to this because I am always giving Matt a lot of grief. I give him a hard time. I did exactly what I've been telling Matt he does all the time. [...]  

Student: (What?)  
PH: I went over to play my computer on the beginning level.  
[There is laughter and giggling going around in the room]  
PH: And, beginning level is not that tough. Now, it is good. It is better than you suspect. But, it doesn't play very well. It just kind of moves. I lost. You know why.  
Students: Ahh.  
PH: Exactly, Matt will tell you why. Because he knows what I am always telling him.  
Matt: You (didn't) think.  
PH: I move too fast. I thought I knew my plan. I thought I knew what I was doing. I know I am better than that silly computer on the beginner level. So, I just started making good moves [gesturing with his fingers making imaginary moves], good developing moves, and all of a sudden, Ahh. I had my queen and my king on a diagonal [making an imaginary diagonal with his fingers]. He moved his bishop on the diagonal [again, PH, demonstrates through gestures].  
Students: Ohh.  
PH: All of the sudden, I lost my queen. And two moves later he forked both of my rooks with a knight.  
Students: Oh. [Laughter]  
PH: I didn't see either one. And this is what I am telling Matt, and I gotta tell myself the same thing. So, no matter how good you get you are never going to get away from the problem of taking time. If we are going to beat every team
we face in the chess club, and you guys on the team are going to win match after match, you gotta take time.

As we saw in (6), PH has instructed his students to look for instances when a opponent moves his king and another piece (rook, knight, etc.) on a same line. In (10) PH talks about his king and queen being on a diagonal (which he creates through gestures). The students’ response “ohh” makes the next scenario happen: losing of the queen. PH often creates instances of straight lines, diagonals, forks, etc. through verbal interactions and gestures. The students are led to not only see these moves but also to create their own spontaneously using the board—sometimes, even with imaginary pieces as illustrated in (9).

Learning to see in the chess club is accomplished mainly through a set of instructions until actions are organized (Amerine and Bilmes, 1988, p. 333). PH’s instructions embodied “seeing” the arrangement of the pieces relative to each other. This is in line of representational thinking where “the very movement of thought and the search for solution are carried out through alternation and transformation of images and the derivation of new images” (Yakimanskaya, 1991, p. 73). The images here are: visual, auditory, and kinesthetic. These descriptions illustrate the kind and the type of visualization as constituted by participants of the Pawns from the Dungeon.
LOOKING AND SEEING IN THE ART ROOM

The Eye is called the first of all the gates
Through which the Intellect may learn and taste.
The Ear is second, with the attentive Word
That arms and nourishes the Mind.

The way we see things is affected by what we know or what we believe. (Berger, 1987, p. 8)

When you see it in your mind, you can usually—more or less—transfer it on to paper whatever you are doing.
(Mimi, 12-14-92)

In this section, I provide the descriptions of visualizations that occur during the study of Salvador Dali’s works in the art room [10-21-92]. The theme of the visual arts curriculum for the entire school during the first semester was about studying the art of Spain. This fifth grade class had previously studied Joan Miró. Ms. Mona Ball (MB), the school art teacher, introduced Dali’s art by way of explaining surrealism (“There were things about that dream that can’t happen in the real world”). The students were guided through sample works (from posters, photographs, and slides) representing Dali’s imagination and dreams. Students got to share their dreams as Karen and John do in (1). Ron pointed out that surrealism “is just like imagination because you can keep your thoughts out and you can just differ from doing, thinking like regular” [12-1-92]. As MB introduced Dali’s art to the class she gave instructions: “Salvador Dali has many dreams and I want you to think about one because that’s what your picture is going to be about today.” Doing or making Dali like pictures allowed the students to externalize their thoughts, their personal experiences. But before
doing/making art, MB's role was to educate the eyes of her students. She
does this by guiding them to look and see deeper into Dali's art. She
succeeds in doing this because she tries to connect what her students know
with the content area she is trying to teach.

MB: I am going to write on the board. It has a word in it that you
know. Real. You all know real and there's a kind of art that
is realism. And, then, there's a kind of art that he does, it
goes past realism into imagination and dreams in our
subconscious. And that's called surrealism, and that's what
we're going to do today. We are going to do some
surrealism. How many of you have ever had a dream about
something that was like real to you? The dream was real
but when you woke up you knew that it really couldn't
happen. There were things about that dream that can't
happen in the real world.
You had a dream like that?

Angela: [Nods.]
MB: Was it scary or funny?
Angela: Scary.
MB: Scary (...). I think a lot of Salvador Dali's dream-like
pictures are scary because I think he might have had a lot of
bad dreams himself. When I was a child, I had a dream that
kept repeating itself. Did anyone ever have a bad dream
that they had more than once? And they hate having that
dream. Have you had one, Karen?

Karen: (Um hum.)
MB: What was yours about?
Karen: (It was about—a kind of scary—but could happen if you
lived on a UFO site.) I had a dream about UFO invading my
neighborhood.

MB: Okay, so (...) it could happen, it could not happen, but they
have not got any proof of them yet. At this point, space
invaders are surreal. [...]

John: Well, my dream is about me jumping off the roof and never
hitting the bottom (of it.)

MB: You never hit the ground, you just keep floating. Okay, well,
Salvador Dali has many dreams and I want you to think
about one because that's what your picture is going to be
about today.
Visual imagination or imaginative thinking is often ignored in the school curriculum (e.g., Greene, 1988). Here, in this school, exercises such as imaginative thinking and sharing dreams through the visual arts attempt to develop the ability of the students to visualize.

In (11) and (12) we see MB providing perceptual awareness (“His backgrounds are like sets in a stage”) and perceptual sensitivity (“How would their faces look with all that goo all over it and everything?”). Perceptual awareness allows the students to focus on the visual details while perceptual sensitivity invites emotional responses (cf. Funch, 1993, p. 96). MB attempts to relate Dalí’s imagination and art content (“He said what if people were born in eggs, what would they look like?”). Such explanations are given so that the students may later learn to incorporate Dalí’s surreal background into their own drawings.

(11) MB: Some of the photographs will be like the big one over there with the Christ in it. [MB directing the students to look at the poster of Crucifixion on the wall.] But, you know, he will have the imagination of putting the Cross up in the air—floating there—to remind these people what happened. And they are standing in some kind of room, you can’t see the far wall. His backgrounds are like sets in a stage. You can picture that like a theatre but there’s no background. You know, there could be a black curtain behind it. (…) He didn’t do backgrounds to look real, he did them to look surreal. So, when he does landscapes, they are surreal. They often have the mountains (…) and some of the mountains have holes in them or little areas that are open, and he made them more like the shape of a real window. So, he could see through things.

The picture of the Virgin Mary has a rose in it there. It is the second picture. And it has like a window frame and you can see through her the landscape behind and there’s a rose floating in the middle of it. He does strange things.
How many of you have ever been fascinated by the idea of even a dinosaur coming out of an egg? Things coming out of an eggs are kind of fascinating. He said what if people were born in eggs, what would they look like? How would their faces look with all that goo all over it and everything? [MB gesturing.] (Turning) around in an egg. But, this is a picture of him, his whole body in an egg and what his face would look like...

Class: (Ooh.)
MB: inside of an egg.
Class: [Laughter.]
MB: He is just a little strange. Don't you think?

MB also discusses Dali's different techniques. For instance, she shows *Christ of St. John of the Cross* and points out that Dali “was interested in perspective and that Cross is just high but this one is way up in the clouds. The ground is way down here, and he is looking at it as if he is up higher looking down on it.”

Figure 6. MB describing to the class.
Martin was intrigued by *Apparition of Face and Fruit Dish on a Beach* where Dali "has pictures that have like pictures in themselves. Like how he forms dogs and faces and stuff like that" [12-3-92]. MB leads her students to look and see deeper into Dali’s art (“He plays games. This is like a dog’s back legs”). Here, through aaahs and ohhs in (13), we find that the class sees the dog completely even before MB points to its head. Simply looking and seeing was not enough, the students are guided to perceive so that they might be able to use Dali’s techniques (or tricks) while they make their own pictures. MB tells her students: “Longer you look at his pictures, the more you see in his art. So, he really wants you to look.” MB also provides the socio-historical context of Dali’s art by telling her students, for instance, how non-catholics were persecuted in Spain.

Figure 7. “Here’s his collar.”
MB: This is a picture, supposedly, it’s like a chalice or a glass, a mug like (...) in a church (...) when you take a communion (...). It is like a chalice but they have parrots inside. See the parrots inside.

Class: (Yeah.) [softly]

MB: Okay, but the bottom is on a table top. [MB directing attention at the picture.] It looks like there’s an eye ball here. A nose, a mouth, and a chin. You see the face.

Class: (Yeah.) [softly]

MB: And he does some other tricks with it. He plays games. This is like a dog’s back legs. This is like his ribs. Here’s his collar.

Class: (Aaah. Ohh.)

[After MB points to the dog's head. Someone yells “that’s neat.”]

MB: (That’s really cool if it can make you look.) The horizon is here. Here is his mountains. He loves the mountains. (And sometimes the clouds (...))
(14)
MB: Well, this is something you should see in this. *It is not just an egg. Who sees it is more than an egg? Who sees South America? Come on, you just made those.*
Class: [Chatter in the room.]
MB: All right, you see it Ken?
Class: (Yeah.) [Chatter in the room continues.]
MB: Who sees Africa?
Class: (Yeah.) [Chatter in the room continues.]
MB: All right, okay.
PH: It's backwards.
MN: No.
Martin: (Yeah, it's backwards (....))
MB: They are drifting off as if they are the egg yolks. And the man is trying to get hatched. Here is his foot kicking up against it. [MB demonstrating.] You see the, I mean, his knee. He is trying to get out of there. Here is his lonely wife and child waiting for her husband.
Class: (Ooh.) [Chatter in the room.]
MB: And what this cloth is I am not quite sure. *You see the horizon line again. (The mountains (....)).*

Students in this class had made paper globes in a previous visual arts activity. MB uses their previous experience to introduce *Geopoliticus Child Watching the Birth of the New Man:* “It is not just an egg. Who sees it is more than an egg? Who sees South America? Come on, you just made those.” In this school, arts are an integral component of the school curriculum. The visual arts teacher works together with the classroom teacher to make the curriculum. The school’s philosophy recommends this approach. PH also participates in this activity. Witness that both PH and Martin are able to perceptually infer (i.e., recognize) that South America and Africa are backwards. Actually, what had happened is that the slide was projected backwards.

Although MB guides the looking and seeing of her students as illustrated in transcripts (10) through (14), her objective is to get her students to use
their imagination to see things in many different ways. On imagination, John Dewey (1934), says that "It is a way of seeing and feeling things as they compose an integral whole. It is large and generous blending of interests at the point where the mind comes in contact with the world. ... There is always some measure of adventure in the meeting of mind and universe, and this adventure is, in its measure, imagination" (p. 267). The class is led to see the adventures of Salvador Dali through his "strange" art. As MB tells her students: "Dali's imagination is just wild."

**Instructions for making Dali like pictures**

![MB drawing and providing instructions.](image-url)
You just take your marker, pencil (...) and make a horizon way back here with some kind of mountains. Maybe a window in them. And he likes body parts. So, people will know that you studied Salvador Dali when you did your dreams. We will put our dreams in here. We will make a sketch of Salvador Dali. Instead of a sun what body part do we need to make it look like it is a sun. Yes.

(How about like a head (...))

Yes.

((...) hair coming out)

So, why don't you make some kind of head up here for the sun. And you put some of the birds in here, you have a big window so you can really see through, and you have another bird in there so you can tell it is a background. And when you color it in, you might want to make your sky interesting and have some different colors in it across. Down in here, this is going to be blank. (...) Sometimes he drapes things. Remember the picture of the clock, the one draped over a dead tree. He often had a dead tree and they looked like a stick. (...) And they had some branches that you could drape something over (...). And you can drape something over it. Then I want you to put the picture of what you imagine here, and name it.

Here, MB is demonstrating to the class how to make a Dali like background by first doing it herself. She refers to Dali’s The Persistence of Memory to the class (“Remember the picture of the clock, the one draped over a dead tree”). While the background is guided by her (e.g., “you have a big window so you can really see through, and you have another bird in there so you can tell it is a background”), the students are invited to make a picture of own (“I want you to put the picture of what you imagine here”). On this process, Emma pointed out to me that “it was like you didn’t have to make kinda like his work but you can take your own dream and your own thoughts and put it in on a piece of paper in his style but not like his work or his things like that. It was your dream on your piece of paper” [12-1-92]. After Emma
volunteered to share her dream (which was about being strangled with a thin fish line by a guy in a black coat when she was reading a book), MB provided some hints on how she could draw (or transpose) her dream on to paper.

(16) MB: You could show either just the man strangling you or you can show like the house opened up. He often did that—like a doll house—you can look right inside. He likes to look through things. So just pull the wall off, make the house, and make you looking at the book, and you can have him lurking somewhere, you know. You have rooms.

MB's suggestion to Emma is based upon Dali's style of being able to see through things, but the picture is to be about Emma's own dream. Gail shared with MB that in her dreams she is "always watching what's happening. I am never in it. I am always watching." Later, she explained to me that she feels so helpless in her dreams since it feels like she is "locked in a cage or something" [12-3-92]. Ron pointed out as he finished drawing his Dali like picture: "In my dream, I was just sitting by a puddle. It was kind a like a puddle, but it was more like a lake. It was small but it felt big. And I was fishing and just slipping into the water. And I would wake up."
Figure 10. Ron's picture.

PH also made a drawing of his dream. PH advises the school's chess club and so he made his "dead tree" look like a dead rook, which he later told his students as he stuck his drawing on to the blackboard in the classroom so that all his students could see.
This activity allowed the students to externalize their thoughts, their dream-like pictures. MB's instructions as she drew (e.g., "make a horizon way back here with some kind of mountains") as well as soliciting ideas from her students ("what body part do we need to make it look like it is a sun?") invited the students to see and to participate in doing and learning surrealism.

Much has been said about the role of visual arts in visual thinking (e.g., Arnheim, 1969). The physicist Richard Feynman invented "Feynman
diagrams" which provided a visual approach to modern quantum electrodynamics. Richard Feynman “had a physical picture of the way things happen, and the picture gave him the solutions directly, with minimum of calculation” (Dyson cited in Shepard, 1988, p. 177). In “What do you care what other people think?”, Professor Feynman tells us about his younger days (p. 54):

When I was a kid growing up in Far Rockaway, I had a friend named Bernie Walker. We both had “labs” at home, and we would do various “experiments.” One time, we were discussing something—we must have been eleven or twelve at the time—and I said, “But thinking is nothing but talking to yourself inside.”

“Oh yeah?” Bernie said. “Do you know the crazy shape of the crankshaft in a car?”

“Yeah, what of it?”

“Good. Now, tell me: how did you describe it when you were talking to yourself?”

So I learned from Bernie that thoughts can be visual as well as verbal.

Later on, in college, I became interested in dreams. I wondered how things could look so real, just as if light were hitting the retina of the eye, while the eyes are closed: are the nerve cells on the retina actually being stimulated in some other way—by the brain itself, perhaps—or does the brain have a “judgement department” that gets slopped up during dreaming? I never got satisfactory answers to such questions from psychology, even though I became very interested in how the brain works. Instead, there was all this business about interpreting dreams, and so on.

Cultivation of visual and other nonverbal forms of thinking (such as imagination) in schools has often been recommended (e.g., Root-Bernstein, 1985). Arnheim (1986) has eloquently stated that “Visual thinking is indivisible: unless it is given its due in every field of teaching and learning it cannot work well in any field” (p. 151). Because of the school’s philosophy,
the visual arts teacher works with the classroom teachers to bring about the connection between visual arts and other subjects. Students begin to develop their "own" ways of visualizing through classroom experiences. The students here learn to perceive and are encouraged to externalize their thoughts. Who knows, there may be a Richard Feynman somewhere in these classrooms.
USING ILLUSTRATIONS ON THE BOARD FOR TEACHING SCIENCE

In the educational practice, learning through perceptual abstractions must be guided by suitable illustrations. (Arnheim, 1969, p. 306)

Words only help you if they make an image, if the words don't make an image, you have nothing. Because I am a right-brain learner, I often, when I can in teaching like this, draw it, so it is a visual picture. So, if the kid is paying attention, he has two senses—both visual and auditory—that is going in to his brain; two ways to help him understand what it is. And I may even draw two or three pictures or illustrate it over to get him to see. I think it is something I always did instinctively. I fully believe in it and now that I understand about left-right brain, I understand why I think it is effective. And, I would say, that is why I do a lot of illustrating on the board—just scribbling little drawings, cartoon figures; and yes, I definitely believe that it enhances the learning, especially for the average and below-average, especially for the right-brain learners. (PH, 1-12-93)

In this section, I give descriptions of visualizations in the classroom that occur everyday during the teaching of units on astronomy and electricity in the fifth grade classroom of Mr. Peter Hart (PH). PH tries to focus on the basic concepts in the science periods. He tells his class: "if you understand the basic ideas, it is much easier to understand the details" [12-15-92]. PH uses the blackboard primarily for drawing illustrations for the class to understand. His drawings are very simple representations of the concepts that he is trying to teach. Often PH uses visual aids such as a painting or a map to make connection among science and other subjects. PH once told

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I made video recordings in the astronomy, electricity, and energy units. I had recorded the first two sessions on astronomy as well as the review session. I had recorded all four sessions on electricity and energy. The science periods usually lasted between 30 to 40 minutes. Here, I am using parts of the sessions on astronomy and electricity.
me that he wants his students to visualize ideas in the classroom. From his quote above and from these descriptions, we come to know about PH's usage of drawings and words to invoke images in his students' minds.

(17)  
UT: When PH says something like use your imagination or see this chess move in your mind or look at this visually, what do you think he is trying to convey?  
Sam: Well, he is saying think of what it would be like and how and why (...). And when he says use your imagination, he means to make different images of one thing depending on what you [are] doing and make out the best thing that would work for that. And, mostly that when he says anything of that kinda sort, that's what he means.  
UT: What do you think, Jean?  
Jean: Well, when he says that, I think he means like try to like think about what you [are] doing and use your imagination—think about the possibilities and don't always think of things as black and white.  
Sam: Yeah.  
Jean: And like try to pick out the little things.  
Sam: Try to pick out the biggest and littlest possibilities of anything and when he says to see something visually: look at it, look what might be there, look what could be there hundred years from now. Look what could be, look what could happen all these sorts of possibilities.

Students in PH's class tend to develop their own images depending on what they are doing as Sam points out. From (17) we find that their images are created in activity not cut off from it. As illustrated in the section, Learning to see in the chess club, PH's sets of instructions to his students in the classroom organize their visualizing.
Understanding our moon

PH began the unit on astronomy by giving his class (with the help of a map) a description of the movement of the pioneers across the United States. He then used a globe to illustrate the idea that “our earth is now mapped, we understand it, we know it. There is not much frontier left. So, now, do you get the picture why do we call space, the new frontier? Because, we don’t know about space” [10-28-92]. PH often uses such analogies to provide insight into the subject matter. At times, PH clarifies naive notions of his students, and he does this through suitable, but simple, visual diagrams. For instance, Keith replies that the moon gives light, in response to PH’s review question on what does the moon do [10-28-92].

(18)

PH: I said the moon doesn’t give off light. And you are going to say, wait Mr. Hammock, I was standing out there last week and I looked up in the sky and that moon sure as heck was light. But, is the moon giving off light the way a star does? Martin, explain.

Martin: Well, the sun reflects its light on (the moon.)

PH: Don’t say reflects (because) that’s a wrong word. Shines. (...) Reflects means that there is nothing there and it bounces off. So the sun does not reflect its light: it burns. It shines its light on the moon. Now, does the moon shine its light on the earth or reflect? Keith.

Keith: Shines.

PH: Wrong. Same problem you were having before. The moon is a piece of dead stone floating in space. It does not shine. Question: does it reflect?

Keith?: Yes. [It could have also been Frank who sat next to Keith.]

PH: Yes, Keith, it reflects the light. That’s why I said it doesn’t have light. The only reason you can see the moon is because it is reflecting the sun’s light. [Now, PH uses an earth model which is hanging from ceiling.]

And guess what happens if the sun and the moon are on opposite sides of the earth. Then you can’t see the moon.
Say, here it is. Oh, there it is. (...) [PH pointing and gesturing.]

Why can't you see the moon? (...) Nina.

Nina: (Because the planet is in the way.)

PH: The planet is in the way. There is no light reflecting off the moon. The moon can't be seen. It is called the new moon. The moon disappears. When you have a full moon, then the light of the sun is shining on it directly. And, Keith, that's another way you can tell.

[PH now draws an illustration of a crescent moon on the board.]

(...). Is the sun ever going to look like that up in the sky?

Class: [Laughter. Someone says “no.”]

PH: No, because it's burning. It is generating its own heat and light. The moon, the little crescent moon, why? Because the sun is only shining on part of the planet [PH pointing and adding to a drawing of the moon and not the earth]. You see the difference. The moon or any moon reflects light, it doesn't give off light.

It is to note here that PH's comment about the occurrence of new moon may be confusing since during this phase the moon is almost between the earth and the sun and so it “disappears.” However, his description of the full moon as well as the drawing of the crescent moon suggests to Keith (and to the class) that “moon or any moon reflects light, it doesn't give off light.” This transcript also illustrates that PH's method of explaining—often repeating—key concepts to his students through words, drawings, and gestures. Before using an earth model or making drawings on the board he had already elaborated to Keith (and to the class) that “The only reason you see the moon is because it is reflecting the sun's light.”

Questions are encouraged in PH's class and his answers also have an integral component of words, drawings, and gestures as illustrated here. PH had just reviewed to the class that a planet revolves around the sun [11-10-92].
Martin: I have a question.

PH: All right.

Martin: Well, (...) the moon goes around the sun doesn't it?

PH: No, well (...) let me explain this. They have (little) models that you can do, and I will try to give you a model here. [PH now draws on the board.] That's the sun. This is the earth's orbit. This will be the moon's orbit.

Martins: (Yeah, I knew that.) [softly]

PH: Since the moon follows the earth, the moon is obviously going to orbit the sun. [PH tracing the orbits.] Yes. But to say this orbits this, we generally mean. Now, let me explain this to you scientifically. The gravitational pull is what it orbits around. [PH gesturing with his hands.] So, the moon is not orbiting the sun because the gravitational pull of the sun is not affecting the moon. Get the difference. The earth's pull to the sun is why we orbit the sun. [PH using diagram for pointing and gesturing.] Why does the moon go around the sun? Because its gravitational pull is to the earth. Get the difference. Good question. Satellites, moons orbit planets. Planets orbit suns.

Figure 12. PH using the diagram and gesturing.
Martin is aware of the orbits of the moon and the earth relative to the sun ("I knew that"). PH's actions here—drawing a model first on the board and then tracing the earth and the moon's orbits—help demonstrate to Martin that the moon, although controlled by the earth's gravitational pull, also revolves around the sun.

**Instructions to see the total lunar eclipse**

PH discussed the lunar eclipse phenomenon in the beginning of a science period on electricity since there was a news story that day on the total lunar eclipse in *The New York Times* [12-09-92].

PH: *Let me explain it by picture because talking to you about it is not going to be a big help. [PH now starts to draw.] This will represent—though much smaller—the sun. This dotted line represents the orbit of the earth. We will call that little thing earth. *E* for earth. And, of course, around the earth is the little thing called the moon. Now you can see that these three things are all going to change in the relationship. [...] I saw [the movie] "solar eclipse"... It was a very bad movie. But, they had some really neat holographs. You know what a holograph is. And it was really neat (...). But, the holographs were great. When they sat there and talked—instead of having charts or pictures or two-dimensional picture on the wall—they actually had the sun as a big you can just see it. And you can see the planets going around it and it was really neat. I can't do that for you. [PH using diagram for pointing/gesturing.] But, *you can imagine the sun stable at this point. The earth as it goes around, the moon is also going to be going around the earth as the earth goes around the sun. So, these three things are going to continue to change in relationship to each other, okay, as they go around.* [PH gesturing.] What's happening in this lunar eclipse time is that because of where the earth is going to be located. [PH erases and draws part of a diagram.] *Now, let's see, this is a lunar eclipse, right?* Yeah, so the earth is (...). The moon is going
to be traveling around behind the earth tonight at about 6 clock. So, what's going to basically happen to the moon is it's going to disappear (...). Because the moon, like you see the moon is the sun's light, you all know that I hope—it's a dead piece of stuff floating through space. When we see what we call the moon is the reflection of the sun's light on it, and the sun is going to be shining on the moon happily.

[PH continues drawing, gesturing, and pointing.]

We are going to see it. We are over here on the dark side of the earth at night. So, imagine us at this side. So, when the moon slips behind. Let me draw this. Let's think of this as earth's shadow. When the moon slips into the earth's shadow. The sun no longer can hit the moon. And once it drops right into this shadow, it's going to disappear because the earth will be in the way [see Figure 13]. And this only happens at odd times depending on these rotations [revolutions]. And it's really kinda neat eclipse because number one you don't have to worry about your eye. Some eclipses were the moon blocks out the sun, you looking up and (...) the moon blocks the sun and then the moon moves and [PH making a sound] you blind yourself.

Figure 13. The moon slips into the earth's shadow.
This is not a problem because the sun has nothing to do with it. You can't even see it at night because the earth is in the way [PH pointing.] You are going to be looking at the moon so your eyes are perfectly safe. And you are going to see the moon and all of a sudden it's just like some magic wand up there in the sky. Somebody is going to start like erasing the moon. And you are going to see it begin. This gray line will start to sweep across it. Go out at about 6:30 or quarter to 7 p.m. and you will see the gray line is like half way through the earth, the moon. And all of a sudden, the moon is going to be gone. And it's weird, if you think about this you will know what's happening, it's just moved into the shadow if you go back out, it [NYT] says it will take about 7:20. If you go back probably about ten to seven or five to seven and go out again and what you going to see. [PH adding on to the diagram.] Peeking out on the other side of the shadow the moon is going to begin to come outside of the shadow [see Figure 14]. The sun will hit it and you will start to see it grow and get bigger and bigger and this little gray shadow will disappear and the moon will be back again. So, it is real neat when it's really easy to see. And this basically explains it. The moon is going into the earth’s shadow and then emerging from the earth’s shadow as it journeys around the earth. [PH using the diagram for summary.]
This transcript illustrates PH's teaching practice: explaining through pictures, gesturing with his hands, and sharing personal experiences to make the concepts that he is trying to teach visible to the class ("But, they had some really neat holographs"). Witness also his classroom discourse style ("We will call that little thing earth") which the students are called upon to see. The illustrations (or pictures or drawings) are drawn and redrawn as he explains ("So, these three things are going to continue to change in relationship to each other, okay, as they go around... Now, let's see, this is a lunar eclipse, right?"). He carries on with the drawing of the total lunar eclipse as he instructs his students about the phenomena. The
representations that he creates and recreates along with his instructions make possible for the students to "see" how the eclipse occurs ("So, imagine us at this side. So, when the moon slips behind. Let me draw this..."). His work during this discussion provides a support for students to perceptually infer (i.e., recognize) the changing relationship of the three heavenly bodies. He ends his explanation with instructions on how to see this particular total lunar eclipse ("Go out at about 6:30 ... and you will see the gray line is like half way..."). PH's vague reference to solar eclipse ("the moon blocks the sun") prompts a question from Jean.

\begin{quote}
(21)
Jean: \textit{If the moon is smaller than the sun, (how can it block it all (...)}. \\
PH: \textit{Proximity. Watch this. I will show you this.} Can you see James? [PH keeping his right hand in front of James.] \\
Jean: Yeah. \\
PH: You can see, can you see most of him? \\
Jean: Yeah. \\
PH: You see his head, his body pretty much. [PH going closer to where Jean is sitting and putting his hand in front of her face.] Can you see James? \\
Jean: (No.) \\
Class: [Laughter in the room.] \\
PH: You can't. Why not? \\
Class: [Laughter in the room.] \\
Jean: (...) \\
PH: Yeah, exactly, proximity. \textit{The moon is very small but when it is right in [your] face it block's out lots of things. In fact my hand, my little bitty hand. You look around the room you see all kinds of things can't you? But, if I put my hand right in front of your face, you can't see anything, except my hands. That's how it works.} [PH using a diagram.] The moon is very, very close to the earth. Hundred and fifty thousand miles does not sound close, compared to ninety three million miles. \\
Class: [Laughter in the room.] \\
PH: So, the sun is so far away, the moon is so close that it can block out the whole sun. 
\end{quote}
PH's demonstration of solar eclipse using his hands reveals to Jean: "The moon is very small but when it is right in [your] face it block's out lots of things." From (20) and (21), we find that through gestures, verbal interactions, and visual representations (which are created and recreated on the board), PH does his teaching. Through his instructions the students in the class develop an understanding on what to look for ("imagine us at this side") and what to ignore ("the sun has nothing to do with it").

"Astronomy pointillism"

PH likes to use arts (e.g., paintings and role-playing) in his teaching because he wants to "make them [students] think; stretch their minds." He told me that before he teaches he first asks himself: "What is the purpose?" (of the material). He, then, asks himself: "How to do it interestingly?" (using the arts). In the astronomy unit, PH connects pointillism to constellations. In the review session, he covers this aspect in a greater detail [11-10-92].

(22)

PH: What do we call a painter who paints with clusters of dots?
This is a kind of interesting connection that could be seen through the arts. Gail.

Gail: Pointillism.

PH: Pointillism. This is a style of using dots to create pictures more so even in the milky way. And one of the amazing thing about pointillist artists is that they spend months or maybe six months to a year doing nothing but putting little dots. And if you got (the little) dots so close together that they make a picture. (...)

[PH goes over a Georges Seurat's painting (on the class wall), Le Cirque, to point out to the class that the dots in the painting are so tightly clustered together.] (...)

PH: When you look at a galaxy. A galaxy up in the sky. You [are] going to think it's a star, and it is really billions of stars. But again they are so close together [they appear close].
And another interesting connection when you think of an artist. Was this guy innovative and clever and [was he doing something] new? Was he doing something different than Monet and the earlier painters? Yes. And you know, he is the fore-runner for something you guys watch everyday for about 5 hours a day according to the newspaper statistics. What else is based on a bunch of dots?

John: T.V.

PH: T.V.

Gail: Newspapers. [softly interrupting PH]

PH: Television is nothing more than a series of dots.

Gail: The pictures.

PH: The pictures. Yeah, you're right. You're right, the pictures are. So again, this pointillism: the idea of dots making colors making pictures making graphs is an interesting concept and it connects in a lot of different ways. [PH now pointing to a drawing of the Big Dipper on the board.]

Now, what do we call back to this kind of pointillism or astronomy pointillism? What do we call a group of stars that has a name?

Karen: (A galaxy.)

PH: Nope. A galaxy would just be a pattern of billions of stars. I am talking about stars that you can count 10, 12, 15 stars in a cluster that we have a name for.

Sam: Constellations.

PH: This should be in your notes, it's constellations.

For Ron this connection was helpful because “it helps you get a better perspective for what you [are] looking at” [12-1-92]. Using works of visual arts such as Seurat's painting not only aided this connection but also made points (dots) less abstract (“television is nothing more than a series of dots”). For PH making this connection (“the idea of dots making colors making pictures making graphs is an interesting concept and it connects in a lot of different ways”) allowed him to later discuss the notion of perspective to suggest that the “constellations are not all up there equidistant from our
PH demonstrates how by closing one eye you lose the perspective; so things appear very close to each other.

(23)

PH: Hold your two fingers. Right in front of your face. Put them side by side and close one eye. Put them apart. Put one close to your face, and one further away. Amazing. So, constellations are not all up there equidistant from our eyeballs. Some of these stars might be way, way for away; some fairly close. But from where we are sitting on earth, they are going to look like that they are all together in a pattern. (…)

PH now holds the book, Follow the Drinking Gourd by J. Winter. This song was sung last year by some students. PH points out that the drinking gourd was a folk song used by slaves for following the underground railroad. The book was to be read later in a Drama class. Some in the class already knew about this book. "Stars," he points, "were used by navigators." (…)

PH: Why the Ursa Major, why the Big Dipper, why follow the drinking gourd? And, there are probably two reasons. One not really important; one very important.

Gail: (Because at night you could see it first.)

PH: Yeah, but even in the daytime people didn't always know (where they were going). But that's a reasonable point. But that's small. Two more important, I think, reasons. Frank.

Frank: The north star.

PH: Boom. (…) Now, in order to understand this. *Ursa Major does not contain the north star, but it's very close to the north star*. The Big Dipper is always in the northern part of the sky. Very important that it pointed north. What's another reason that this would be a good thing?

Sam: Well that it showed where the real dipper was that had the north star.

PH: But, a lot of those slaves probably didn't even know that. It was close to north that was close enough.

Beth: (It was like (…))

PH: Well, that's right and that's why they did travel at night. But I am talking about why (…) the Big Dipper. Just an interesting thing about constellations.

John: (Because the Big Dipper, the north star, (…))

[As John talks PH draws four examples of constellations.]

PH: *Okay, I am going to give you a demonstration, folks. Look I just drew some constellations.* Here's one constellation,
here's another constellation, here's another constellation, here's another constellation, okay. Which one do you think you can find easiest in the night sky? Oh, really. How many think you can find this [constellation 2] in the night sky? What does it look like?

Class: (A bunch of stars.)
PH: What does this look like? [constellation 1]
Class: (stars.)
PH: What does this look like? [constellation 3]
Class: (stars.)
PH: What does this look like? [constellation 4]
Class: (A circle.)
PH: (... So, you are starting to understand why the drinking gourd was real important. How many of you could see the gourd in the sky? How many of you could see the dipper? Two real important reasons: constellation that is probably the easiest of all constellations to see and it was in the north.

PH's demonstrations often involve the entire class. His four illustrations had a purpose: to show his students that the drinking gourd was important because it was the easiest of all the constellations for the slaves to see.

PH's connection of pointillism and drinking gourd to bring about the understanding of constellations reflects the school's philosophy: to infuse arts into the learning curriculum.

These few instances from the astronomy unit illustrate how visualization in this classroom everyday is organized through classroom interactions. Let us now look at some instances from the electricity unit to find out if there is any similarity in the descriptions of visualization with the astronomy unit.

**Structure of the atom**

PH begins the unit on electricity with a discussion on the structure of the atom. PH begins by providing an analogy between the representation of the atom and the solar system [12-08-92]. He does this by using the diagram of
the atom, gesturing, and saying: "The solar system has the sun in the middle
and has stuff flying around it. So do atoms." What PH wants the class to get
is that the pattern of the nucleus and the stuff flying around it is closely
related to the solar system. But unlike the solar system the "nucleus is very
tiny."

(24)
PH: So, the structure of the atom has some basic parts that are
very important. One is the nucleus. That's the middle of the
atom, and if you think of like the sun and the solar system,
that's a quick comparison. Both are science ideas and both
are very closely related.
[PH gesturing.] The solar system has the sun in the middle
and has stuff flying around it. So do atoms. The weird thing
about atoms—we will talk more about this—is that they are
so small, and they have so much space in them because all
this here [PH using the diagram of an atom drawn on the
board] is just space. (...) The nucleus is very tiny and the
electrons are very tiny. But we will deal with that more later.
Just get the patterns. Yes.

Gail: Where is this? Is it in your body?
PH: Where's what?
Gail: Atoms. The atoms.
PH: Everything in the whole universe of what we know is made
up of atoms. Desk, chair, your hair, your finger nails, the
pencil, the mucus in your nose, the wax in your ears.
Everything is atoms.

Although PH points out to Gail that everything in the known universe is made
up of atoms through several examples, he gives her and the class another
analogy between the elements in the periodic table and the alphabets in the
English language and points out that: "You can create all kinds of images
and ideas with those twenty-six letters." PH usage of such analogies aided
by his drawings and gestures tend to facilitate thinking visually in this
classroom.
PH: In response to Felicity's [Gail's] question, everything in the universe is made up of these and approximately one hundred different atoms. Everything is made up of the same one hundred atoms. I find that pretty strange. (...) Here's another comparison. All the words in the English language—in our language—all the words are made up of twenty-six letters, but the combination of the letters, you can get anywhere from snot and manure to glory and hallelujah, and god and the devil. You can create all kinds of images and ideas with those twenty-six letters. Twenty-six elements, folks. Oh, I mean a hundred—about a hundred—elements. These are called elements; it's another name for an atom. So, they come in different sizes and shapes. Some have whole bunch of protons and neutrons; some have one or two.

PH tries to connect concepts from different science units as well as between science and other subjects—his explanation of neutrons and electrons below illustrate this connection. He begins this segment by first pointing out from his diagram that "P" stands for protons which are positive.

PH: Neutron sounds lot like neutral. When we talk about war and we say Switzerland is neutral, what does that mean? They aren't on either side; they are just on their own.

Sam: They aren't on either side; they are just on their own.

PH: Exactly. It's same concept in science just like the concept in social studies. To be neutral is not take sides. In the revolutionary war in this classroom, is there anybody who is neutral? I haven't see many.

Emma: (Well, I am on both sides (...))

PH: Actually, one year I should assign some people to be in the middle (...). But, anyway, neutral is not to take sides. So a neutron has no charge; it's neutral—it's not plus, it's not minus. [...

PH: Now, we get to E. Different part of the atom called the electrons. Notice in the picture, it is not in the middle, but like a planet orbiting the sun, the electrons actually spin around [PH gesturing an orbit with his fingers] the nucleus. And they have a very important job and that is they are (...
negative, minus. When we deal with electricity, we going to have to understand the pluses and minuses—very important idea.

PH's analogies tend to bring about a connection in the classroom between different ideas. By making the statement, "In the revolutionary war in this classroom, is there anybody who is neutral?", PH makes an effective correspondence between the neutral charge of the neutrons and the position of taking no sides in the revolutionary war in the classroom (role-play done previously in some social studies period). The students are, then, directed to "notice in the picture" that the electrons, like planets, spin around the nucleus. Note that he has already established a connection of the nucleus of the atom to the sun in solar system in (24).

What is lightning?

PH here discusses lightning as an example of static electricity [12-08-92]. As also pointed out in the section, *Instructions to see the total lunar eclipse*, the visual representations (drawings) that PH creates, recreates while he discusses science facilitates his students' understanding. PH likes to share his personal experiences using descriptive language ("I was on the porch looking at this beautiful rainstorm") to describe a concept. PH told me after the end of this class period that his students "are learning about science [electricity] through these stories. It makes connection." PH not only explains to his class how lightning grounds itself through examples, but also points out what can lightning do ("If it hits a tree, sometimes it explodes"). He provides instructions and draws as he explains the situation visually ("let's
imagine we are in Kansas, and there is a thunderstorm which means there is
lot of negative charges in the sky"). This is how he makes the phenomena of
lightning visible to his class.

(27)
PH: Here's another word that you should know and hear.

*Lightning grounds itself and whenever we say it grounds itself we are basically saying it neutralizes itself.*

Sometimes electricity will travel right through whatever it is and ground itself in the ground and the person will not be hurt at all. [PH continues to draw.]

If the house has the lightning rod that sticks up high into the rest of the house. And the lightning zaps that, it will go through the rod right into the ground and ground itself.

[PH drawing another diagram.] If you didn't have that lightning rod and there was nothing up higher than the top of your house, the lightning gets the roof of your house.

Class: [Aaah in the room.]

PH: (...) Now this is the weird part, it could explode and cause a damage or it could run down the walls and go back into the ground.

PH: [PH draws another diagram.] *If it hits a tree, sometimes it explodes.*

We had a tree in our yard. This happened, in fact, this happened when I was standing about twenty feet away and I never jumped so high in my life.

Class: [Laughter in the room.]

PH: The lightning struck the tree, *I was on the porch looking at this beautiful rainstorm.* The rain is pouring down all around me, and Jan is in the house saying, "Paul, you sure you want to be out there." But we have this covered porch and I was not getting wet and it was just beautiful and it was the smell of the rain and pouring rain. And there was actually not much lightning. And all of a sudden,

Class: [Laughter and chatter in the room.]

PH: I mean sudden (...), I jumped about sixty feet. The lightning hit the tree right near our house. And we found this later. It was really strange, it broke one limb, but all the way down to the dirt there was a strip of bark (...) about an inch wide and it just pilled the tree all the way down into the ground.

PH: It's the weirdest thing. And I know it for fact it hit that tree because I was standing around when it happened.

Class: [Laughter in the room.]
(I didn’t go after that and see this), but this little piece of bark was all curled up [and] lying on the ground. And it is the strip of bark about forty feet long that had come all the way down. So, lightning is a very queer thing in what it does. But, what it’s trying to do is all that negative energy up here is looking for place to ground itself. [PH using the diagrams.]

Now, why do you think, folks. [PH draws another diagram.]
This is a field. Okay, let’s imagine we are in Kansas, and there is a thunderstorm which means there is lot of negative charges in the sky. Why do you think people tell you, I am sure your mother said this at least once, not to walk across the field in the middle of the lightning storm? What now scientifically can you tell me the reason why?

Beth: (Because you can get struck by lightning.)

PH: You can get struck by lightning because that lightning is going to try to do what.

Gail: (It’s going to go through (...))

PH: It’s going to go through some to ground itself. Is it going to hit what’s down here? Or down here? [PH using the diagram.] No, it is going to hit what is closest to it. And if you are the tallest person in the field. Now, of course there’s another problem. People say don’t get under a tree during a thunderstorm. Now where’s the lightning going to ground itself?

Sam: (On the tree (...)) [Another student whispers “on the tree.”]

PH: What might the tree do?

Class: [Laughter in the room.]

Sam: (…) (It might fall down and) charge it onto you.

PH: It can charge it onto you or just knock the tree down; it will hurt you.
To answer John's question, PH makes an illustration of lightning hitting water. He points out to John that "water is all connected" and later demonstrates through gestures: "if you just speak, sound goes everywhere." He then provides analogy between the tree planted in the ground and the megaphones the cheerleaders use. He makes a megaphone shape with his hands.

(28) John: I have a question. Do you know when lightning hits water or lightning goes in water, why is it dangerous?
PH: Because, in essence, what is happening is that the negative charge when it hits the water [PH draws an illustration] it's going to send that electrical charge throughout the water.
Water is all connected [PH gesturing]. Unlike a tree planted in the ground, it's going to go directly through that tree. But, if it is water, it will dissipate—that's the word. It will go throughout the water and if you are out here swimming around you (...) can get some of that charge and that neutralizing charge can go through you as it is going out because see when it hits water understand too that it does not have a direct path. Okay. You know the megaphones the cheerleaders use, they want to focus their voice. (...) [PH speaking through a megaphone shape with his hands.] But, if you just speak, sound goes everywhere [PH gestures]. (...) In the water [it] is very different from the tree because the tree is like a megaphone. (...) It goes straight down into the earth. (...) But, if you hit water, that electrical charge is going to go everywhere because water is all equal in all directions, all sides. It's going to go farther and it's going to be dangerous to be (in it).

What is a short circuit?

PH usually directs his students to read a topic from the book and then he "talks" about it in the class. The class has just gone over the basics of series and parallel circuits, and now PH is providing further examples of parallel circuits [12-14-92]. Here, PH is trying to set an example which will relate to his soon to follow discussion on the short circuit. So, PH redraws his illustration on the board ("This isn't done very well"). The illustrations drawn on the board by PH are simple and the students are regularly called upon to develop ways of visualizing these illustrations ("little circles represent light bulbs") to understand his explanations (e.g., "you can turn off a light in any place in the house").

(29)

PH: These little circles represent light bulbs. This is like the kitchen [pointing to bulb 1], this is the bathroom [pointing to
bulb 2], this is the living room [pointing to bulb 3]. What happens is when that light bulb [bulb 2] goes out. *This isn't done very well* (...) [PH erases and starts to draw]. Because I want you to see this because there is one more idea I want to get to you before (...). These light bulbs in the kitchen, dining room, whatever. The current can go up through or it can pass around on by. *In other words, these are connected.*

So, if this light [pointing to bulb 2] is out, it can go right on by and around. If this light [pointing to bulb 3] is out, it can come right back around this way. If these lights are both out, it can come back around this way [pointing to bulb 1]. So, you can turn off a light in any place in the house and the circuit, if this one is on [pointing to bulb 3], then it will carry around to here and come back, it will just skip this one, you see [PH tracing the path]. If all the lights are on, some of the electricity will go through each one and some will go back.

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Figure 16. PH tracing the path.
PH often covers topics that are not mentioned in the textbook. For instance, he discusses short circuit in the class which is not covered in the book. Making illustrations on the board is a major component of PH’s teaching style for topics not covered in the book. I asked Sam about short circuit and he said: “I thought that the short circuit was like when the power was just dead and so seeing that I thought that okay, so I know that’s short circuit and what can happen” [12-16-92]. For Jean, the illustrations that PH draws show her how the short circuit works: “If he just says like that it actually makes the circuit shorter then it will come back, I mean it doesn’t give you any idea of where it’s going to come back and stuff. But if he draws he shows you where and how” [12-17-92].

(30)
PH: What is going to happen on this wire right here with two wires in it like an extension cord? What is going to happen if these two wires touch? Like the rubber gets broken on the (code). What is going to happen to these negative electrons that are flying this way? These positive ones coming back. What’s going to happen if that wire connects and they touch? [see Figure 17.]

Sam: Electricity (...)
PH: Electricity is going to go because wherever there are negatives they want to go to positives. Now as long as that wire is around them—the rubber is around them, no problem. But when they touch, there will be sparks, yes. What is that? Just like static electricity. What is going to happen to the circuit, folks?

Student: (It’s going to be a short (...))
PH: It’s going to go short. If these two wires touch then all the electrons here are going to wrap right around here and go back home again. Would you call that a pretty short circuit?

Class: (Yeah.)
PH: That’s exactly where it gets its name. In other words, you’re (going to) get no light here, no light here, no light here. Why?
You have a short circuit. What is a short circuit? It is a circuit shorted out. And that's what that actually means, literally it is shorter from the electrical (plug) to this short circuit here and back again. Now if I take these two wires apart so they don't spark anymore, why should I wrap them in tape? If it is damaged, why do you think people wrap them in an electrical tape, black electrical tape?

Jerry: ((...) because it is a (...) insulator.) [Another student also says insulator.]

PH: It's an insulator. And two things happen. One is you are not going to have sparks jumping back and forth. So, it is safer (as those) sparks can cause a fire. That's why short circuits are very dangerous. Second reason is now what's going to happen to your light bulb?

Student: (...) 

PH: They will all (...) hopefully they will light up.

Figure 17. "What's going to happen if that wire connects and they touch?"
Sam and Jean's understanding of short circuit is facilitated as PH relates to what he is saying with the drawing on the board ("If these two wires touch then all the electrons here are going to wrap right around here and go back home again"). Witness, again, his discourse style as it switches from less formal ("wrap right around here and go back home again") to formal ("It is a circuit shorted out"). The students have to develop not only ways of visualizing PH's illustrations but they also have to relate his informal style of speaking to learning of the science concepts.

Classroom interactions generally have three forms: transmission oriented, collaborative, and reflective (cf. Wells and Chang-Wells, 1992). In the science periods, we find that PH's instructions are primarily transmission oriented (lecture format). PH discusses the basic ideas in astronomy and electricity through simple visual diagrams. These diagrams are created and recreated along with his instructions for the students to see and to understand. Along with making diagrams PH's teaching practice has two additional features: gestures and informal style of speaking. Witness, for instance, his instructions to the students about the total lunar eclipse: "This will represent—though much smaller—the sun. This dotted line represents the orbit of the earth. We will call that little thing earth" (20). The students are guided on what to see on the board. PH's illustrations and gestures are generated in activity as he explains to his class; for instance, his drawings and gestures to John explaining that water is all connected (28). Students, then, tend to develop a situated sense of visualizing in the classrooms organized through his instructions. However, PH's instructions in the science periods are different than his instructions in the chess club meetings.
where his main intent is to instruct the club members into ways of seeing the chess board. This he does by providing verbal scaffolding so that the students can learn to use strategies such as discovered attacks. The objective for the students is to win games. In the science periods, PH's focus is to facilitate visual thinking in the classroom through suitable diagrams, gestures, and analogies (using visual aids). PH's everyday practice of teaching provides support for perceptual learning.
ROLE-PLAYING IN SOCIAL STUDIES

Role-play helps them [students] to really own and by owning it, understanding it. (PH, 1-12-93)

It [role-play] helps you get a better character and helps you learn more. (Emma, 12-1-92)

In this section, I describe role-playing in the classroom of Mr. Peter Hart (PH). PH uses role-play in teaching of social studies; for instance, to discuss the way of life in colonial America. PH believes that role-play brings ownership of the material to his students. For Ron, role-playing helps keep his imagination going. To participate in the role-play about colonial America, the students first assume colonial names. Ron is John Adams. Sam is Jacob. Emma is Annabel. And so on. PH is Rev. David Cooper (DC), the town preacher. The class is divided into three English colonies: New England, Middle, and Southern. There are flyers posted around the classroom reminding students about the town meeting.

These town meetings are for all three English colonies. So, for instance, when the town meeting is for the residents of the New England colony, the rest of the class becomes the audience. The town meeting for the New England colony is in session here [11-24-92]. Often the role-play is stopped in between where DC "cuts" and being out of role (as PH) gives instructions to his students. After he finishes his instructions, PH is back in role as DC: "Next time I speak to you I will be back in role."
I am not actually going to give letter grades to you, but those of you who make good speeches and make good points and listen to each other and respond intelligently, that's going to help you. It's like bonus points for when I average your grade. So, I like to see as many of you involved as possible. You don't have to be in this role-play. But I am noticing those of you who make good points... *Notice too which colonies we are in.* And listen audience, because you are going to hear comments which you agree with or disagree with. Some that are appropriate, some that are not. And when we are finished, we are going to talk about the three role-plays, the differences that you saw in me and the other people in their comments and their attitudes. *So, keep all this in mind because this is a part of our social studies.* *Hopefully that we are learning about the colonies.* The other thing I like to work on all of you with and this will be true in drama. *Think of character.* Think of your age, think of the way you sit... Accents are kind of hard to do, but sometimes just a different voice from your normal fifth grade voice helps you to stay in character.
PH wants his students to come up with original ideas in their role-playing. Jean told me that role-play "helps you because it's like you put yourself in the place of the people that had to like disagree or agree with the taxes and it helps you understand like how they felt about it. ... You have to know that there is no right or wrong of what you think because you are in a role" [12-3-92]. Through role-playing, the students learn to know more about the colonies they represent.

(32)

[DC, the town preacher, enters the room along with other town council members. Elizabeth rings a hand-held bell to start the meeting.]

DC: How are you?
Paula: Fine.
DC: Nice to see you out in this cold weather. How are the children?
Paula: Fine.
DC: Let's get seated. Can you start the fire for us, John? I know it's a cold night, I am glad you folks came out.
[John kneels down to create an imaginary fire.] That will be good. We can warm ourselves by it. It will get better. All right, let us begin our meeting with a prayer.

Bow your heads:

Oh Mighty God,
Be with us today as we talk about these tough decisions here in Cedar Falls.
We have choices to make,
Be with us in all those choices.
In God's name,
Amen.

Council: Amen.
DC: All right, I will call the meeting to order. Annabel, do you have the minutes of the last meeting?
Annabel: Yes, we decided what to do with the animals that got loose in the street.
DC: Jacob, what finally happened to those... Did you slaughter those pigs?
Jacob: Well, most of them, yeah.
DC: Well, we got people to know it. If their animals are going to get loose, they are going to be the town property. We will
slaughter them and give them to the McIntoshes, that family that needs the food.
What's our first order on the agenda tonight, Annabel?
Annabel: To hire a teacher.
DC: Hire a teacher. Anybody wishes to comment? Please stand up and give your name for the record. You may rise.
Elizabeth: I wish to be the town school teacher.
DC: Nominating yourself. That's fine. Take a seat, Elizabeth. We will see if anybody wants to speak for her. Anybody wish to speak for Elizabeth?
Jacob: Well, she...
DC: Rise so we all can hear and state your name for the record.
Jacob: She has a loud voice.
DC: Jacob, we all know you (...), but we need it in the records so that Annabel can take the notes.
Jacob: My name is Jacob.
DC: Thank you. Go ahead.
Jacob: Elizabeth, here, she has a nice, loud voice. And (...) she seems to have children, she knows how to discipline them and to teach and I think she would be good for (it).
DC: All right. Well, anybody else wishes to speak for her? Make other comments? Go ahead, Kathleen.
Kathleen: (Well, I want to be)
DC: Please tell us for the record so Annabel can get your name.
Kathleen: (...)
DC: I haven't heard any of you talking about your knowledge of the good book [waving the science book]. I don't want anybody teaching our children that can't teach them right or wrong. I don't care how many children you have. There is nothing good about God's creatures having children. But, knowing his word is a little more important.

Here the role-play begins with a town meeting where the people discuss an issue (from the previous meeting) of animals getting loose on the street. Then, they discuss the first issue of the meeting: to hire a teacher. We see here Jacob speaking on behalf of Elizabeth. The students learn to make points on the spot. DC [PH] primarily serves as a facilitator and directs the role-play. For instance, he stresses the importance of the Bible [the good book] in the colonies. The students don't get to vote on the teacher due to
time constraints, as PH points out. A "cut" is made as most people end up nominating themselves. PH gives a short instruction to remind some students to pay attention and the role-play continues.

(33)
DC: All right, we got a second issue here on the agenda that needs some talking about. There has been lot of talk in Boston and New York, Philadelphia about this new tax that has been put on all of the colonies. I am sure you heard about the gossip in the corner store. What do you think about the tax being levied against ship building in the New England colonies? Go ahead.

Elizabeth: Well, I think that we should pay this tax because we should all (be able to go back to England and see ())).

DC: So, you don't mind paying (this new) tax?
Elizabeth: [Nods.]

DC: Okay, thank you for your word. Please again state it [name] for the record so Annabel can get who spoke at this meeting.

Elizabeth: Shannon. Elizabeth.

DC: Thank you, Elizabeth. Go ahead, John.

John: Well, I think this is just terrible. (We can't just put all those taxes on us and one more big tax like this and I am going to be ())).

DC: How many ships do you build in a month down there at your ship yard, John?

John: About six or seven.

DC: Can you afford to pay the tax?

John: [Nods.]

DC: And still pay your workers or will you have to cut their price?

John: I will have to cut their (price.)

DC: Okay. Yes, Kathleen, go ahead.

Kathleen: [Stating her name to Annabel.] Well, I don't think we should pay this new tax (because we are over here in this colony and the king is over there and we can't afford to pay.)

DC: Can't afford to pay. Jacob.

Jacob: Well, I have to build ship sometimes to go out and fish and things like that and paying a 100 pounds for a ship that stunk. It's not right and I think that we can build ships over here for our own needs and if we are going to use some for the England needs, if we are going to do that, then we will pay the tax, but only then. Other than that, no tax.
Well, the ships will be able to sail between... Go ahead, Annabel.

But, the king is one who brought us here. We should pay him (so we could be able to come here and live our own lives.) So, we should agree to pay him. It's thanking him—giving him money—for what he did for us.

Here we find that the New England colonists such as John Adams and Jacob are worried about the ship building tax. Later when the Middle colony role-play is held, these colonists are not worried about the new tax since ship building is primarily done in the New England colonies. The Middle colonists do not want to dispute the king as they are afraid that he might levy tax on pottery, for instance, which seemed to be the primary source of income (in the Middle colonies).

The students are understanding issues pertaining to their colonies by "doing" the role-play. The students are encouraged to make original points. PH also discusses issues surrounding the colonies outside of the role-play. For instance, PH draws a map on the board to discuss how people made money and the importance of religion in these colonies [11-25-92]. Printed documents and photographs posted in the classroom also provide information to the students.

Unlike in the visual arts period where students externalized their dreams by drawing Dali like pictures, the students here demonstrate their understanding through acting in the role-play. The students get to know aspects of colonial America from many points of view.
DIAGRAMMING SENTENCES

It [diagramming] is better to understand the sentence because it's just putting it out in the way, in the order, that it should go and it's a lot easier to understand it. (Ron, 12-1-92)

A diagram of a sentence provides a picture of its parts. Although the current trend in many elementary schools is not to use diagramming, Mr. Peter Hart (PH) uses diagramming because it "helps visual learners" [11-18-92]. Martin pointed out that diagramming a sentence puts together things that go together. In this fifth grade classroom, students are in three groups: Nouns, Verbs, Adjectives. Students who are in the Nouns group are very good in diagramming the sentences. PH likes to give his students responsibility by often letting them do their own grading as illustrated in (34). While he solicits answers from his students, PH provides longer explanations on the board for students who are in Verbs and Adjectives groups [11-18-92].

(34)

PH: You need to look at your paper while we do this on the board. You need to mark what you missed. You guys who are in Adjectives add what you didn't put so you can see the right way to do it. Correct your papers, grade your papers. I will not collect this, but those of you who listen and watch and ask questions will learn. Those of you who sit and daydream and look out a window or just throw your paper in the waste basket are not going to learn. You are going to miss the same thing over and over again. Lois and Karen, for example, are missing the direct objects. Every time I see their diagrams, I look to see if they are getting the idea of it. I am your teacher, I can help you. But, you got to help yourself by looking at this work. And, again, I am going to ask how many people got this all right. [This is] very important.
PH is reviewing diagramming here by giving his students five sample sentences. I illustrate two of these sentences. The students are first given time to do the diagramming themselves. As students give answers, he draws the diagrams on the board while providing explanations. Ron (Nouns group) is invited to point out the parts of the sentence: Pods eat catsup on late afternoons.

(35)
Ron: "Pods" is the subject, "eat" is the (...), "catsup" is the direct object and prepositional phrase is "on afternoons" and (...) is under afternoons). [PH makes a sentence diagram as Ron speaks.]
PH: Now, why is it ["late"] under afternoons?
Ron: (...) describing it.
PH: It is describing it. Now, folks, this is another good distinction. He gave exactly the right answer. "On late afternoons," late is describing it. But if I say I was late, then it is not describing anything, it's an adverb. Very good. How many of you got the word "late" underneath afternoons? Give yourself two points because that is the adjective in this sentence. Many times "late" will be an adverb telling when but here it's describing a noun. Very good. How many got the sentence right all together? It is pretty easy. Give yourself another point. Look up here for a second, folks. The biggest problem with diagramming that I used to tell the seventh graders. Are you watching, Laura? Thank you. (...) There are two nouns in this sentence besides the subject. Most kids with a little help will know what a subject of a sentence is. Good for them. There are two more places where nouns can go: direct objects and in prepositional phrases. It's not that hard once you start thinking. Don't just start plugging (...) the words in there. Think. What does it "eat"? "Catsup." On what days? "Afternoons." But I'll get sentence after sentence after sentence where those of you who see a noun will stick it up here because you think it's a direct object. Think about it. This is a very basic sentence, it's not hard.
Pods eat catsup

afternoons

late

Figure 19. Diagram of Ron's sentence

Although Ron gives the correct answer, PH provides a detailed answer for the benefit of other students ("Look up here for a second, folks"). He does this by using the diagram on the board and also cautioning his students not
to just “plug in” words but to think through the diagram (“what does it ‘eat’?”).

For Emma (also in the Nouns group), a sentence diagram helps in figuring out “what word is what part of speech” [12-1-92].

Keith (Verbs group) does another sentence: In the early morning on saturday in summer I sleep in.

(36)
Keith: “I” is the (subject).
PH: It’s a pronoun... Yes, it’s the subject.
Keith: “Sleep” is the verb.
PH: Stop right there. How many got this right? Give yourself two points. I will tell you, there’s a lot of middle school kids, there are probably high schools kids, who wouldn’t understand this sentence.
There’s all these words in the beginning, but see how easy it is for you guys. You know what part of speech “in” is. You know what part speech “on” is. (...) “Morning” is not the subject, “saturday” is not the subject, “summer” is not the subject. You guys are very smart, you don't even know how smart you are.
But, you are absolutely right, “I sleep.” Give yourself a point, if you got the subject and the verb right.

Class: [Chatter in the room.]
PH: Before we deal with the rest of the sentence, let’s look at the word in the end. [PH pointing to the sentence.]
In your notes, what does it say the word “in” is? What part of speech? Frank.

Frank: Preposition.
PH: Preposition. Look at this sentence. How many people see a prepositional phrase?

Class: [Chatter in the room.]
PH: (...) after this “in”... There isn’t a noun after...
So all of a sudden a word that is nearly always a prepositional phrase changes. It is not a preposition in this sentence. This word... Because there’s no noun after it, there’s no phrase.

So, what is the word “in” tell? Keith.

Keith: (Direct object.)
PH: No. You can’t “sleep” the “in.” Because the “in” does not name anything. You can’t have a direct object after “sleep.”

Class: [Chatter in the room.]
PH: Does it tell where?
Keith: (Yeah.)
PH: Where do you “sleep”? How many of you got “in” as an adverb? Raise your hands. Give yourself three points. That is tricky. If you missed it, learn from it. A word all by itself like “now” or “late” or “in” when it just tells where or when, it’s an adverb all by itself. Now, the rest of the sentence is three what, Keith?
Class: [Chatter in the room.]
PH: what?
Keith: (three (...)) [softly]
PH: three what?
Keith: Three prepositional phrases.
PH: Yes. And folks, I don’t care where you put them [PH drawing lines]. Some of you hang them on after “in the morning,” “on Saturday,” you can do that way if you want to. Or, you can put it up here, you can put it down here. There are three prepositional phrases any where they are in there I will give you credit for it. “In early morning” is the phrase. “On saturday,” two word phrase. “In summer”...

Figure 21 shows Keith’s only error since the word “in” is not a direct object but an adverb (“where do you ‘sleep’?”). PH provides an explanation (“A word all by itself like ‘now’ or ‘late’ or ‘in’ when it just tells where or when, it’s an adverb all by itself”) which helps Keith in modifying his diagram.

Figure 21. Part of Keith’s sentence diagram.
PH also makes diagramming fun by assigning sentences as mystery problems to his students. He provides Sherlock cases to his students (see Figure 23 for an example) where the students are required to write the sentence, diagram it, and provide explanation in complete sentences. PH told me that such exercises teach students humor, reading, grammar, and dialogue [11-18-92].
A Case for Sherlock ...

"Holmes!" cried Watson. "The murder was committed last night and the suspects are all gathered here?"

"A murderer!

This note is our only clue:

"Twas sent by an ogre"

"Elementary, Watson! First we'll put this melody in order, and then with the help of my clever scheme we'll explain the innocence of each... leaving... the murderer!"

CAN YOU DO IT?

1) Write the sentence.
2) Diagram it.
3) In complete sentences explain why all words but one are innocent.

* a diagram, of course!

Figure 23. "A case for Sherlock ..."
Martin (Nouns group) first wrote the sentence: A murderer struck outside with the wind howling with force. Figure 24 is the diagram of this sentence.

Martin's explanation in complete sentences [original emphasis]:

"I can't believe it Sherlock! I solved the mystery before you did! Using my great detective skills I have figured out that the adverb has committed the murder. The adverb is with."

"My dear Watson," said Sherlock. "When will you ever learn? Any 5th grader in room 207 knows that with is a preposition, and that outside is the adverb. We both figured out easily from our clue (adv) that the adverb is the murderer. So Watson, you now understand that outside which is the adverb is the murderer.

PH uses diagramming as it is a visual tool for teaching grammar to his students. PH pointed out that by simply dissecting a sentence—for instance, Joe went to the store—does not teach the students the order and relations of its parts. Also, mystery problems encourage his students to create dialogue in their own ways while learning how to diagram the sentences.
WAYS OF KNOWING CUBES, PYRAMIDS AND LINES

The teacher came into the class carrying a large cardboard cube. She placed it on the desk in front of her and asked the class what it was. They said it was a cube. She asked what a cube was, and they said a cube contained six equal square sides. She asked how they knew that this object contained six equal square sides. By looking at it, they said. "But how do you know?" the teacher asked again. She pointed to the side facing her and, therefore, invisible to the students; then she lifted the cube and pointed to the side that had been face down on the desk, and, therefore, also invisible. "We can't look at all six sides of a cube at once, can we? So we can't exactly see a cube. And yet, you're right. You know it's a cube. But you know it not just because you have eyes but because you have intelligence. You invent the sides you cannot see. You use your intelligence to create the 'truth' about cubes." (Belenky, Clinchy, Goldberger, and Tarule, 1986, p. 191-192)

The unity of words and visual aids bring about a close connection and proper correlation of the visual and the abstract, the specific and the generalized; it leads to a connection between the object (image), the word, and the action. (Leushina, 1991, p. 166)

In this section, I give descriptions of how fourth grade students visualize simple geometric shapes such as cubes, pyramids, and lines.13 Ms. Trudy Parker (TP), the classroom teacher, told me that she is a very hands-on person and so she tries to provide visual and tactile understanding to her students [1-21-93]. TP assumes that each student comes to school with visual thinking skills. Her classroom instructions here will illustrate to us how she encourages those students who need help to get started in using such

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13 I made four video recordings of math periods in this classroom. Here, I am using two periods where the classroom interaction was audible. I also use the informal interviews which I made with students to present these data.
skills. TP tries to make her class "connected" (Belenky et al., 1986, p. 223) so that every student is encouraged to form her/his perspective and also make it public by sharing with others in the class. Only through these classroom interactions between students and teacher do we understand the visualization process and their visualizations are organized in activity.

**Becoming blind in the reading period**

In one short reading period after a math period [12-15-92], TP is trying to lead a discussion on an excerpt from the story, *Child of the Silent Night* by E. F. Hunter. However, she does not tell her intentions directly to the class; instead, she places a plastic bag containing 5 to 6 items (such as a calculator, a marker, a hole-puncher, a coffee/tea pack, a soap bar, and an apple) on each table for the students to work. She starts this activity with the following instructions.

(37)

TP: What you are going to do is without looking—now this is really going to be challenging—you are going to put your hand in a bag. Now, if I were you it is a lot easier for me to visualize things, if I close my eyes and I really take a little time, probably one, I tell you what that's what all of you can do. Rest of you at the table, you watch the red hand—the red second hand. Give each person two whole minutes to feel everything. When the two minutes are up, just go very quietly like that. (...) Then the person takes the hand out of the bag, doesn’t say a word to their neighbor. They pass it on. While they are doing it, while they are looking in the bag, you are writing down what you found in your bag. Then you turn your paper over.

TP’s instructions continue as she walks around the class observing the children at work as she reminds them with “don’t forget: do not look, close
your eyes," "no one can talk during this," and "don't take anything out of the bag." As it will be apparent, TP in (37) is trying to provide her students with the experience of seeing things by feeling (touching) them and not by looking at them. She shares her own way of doing—"it is a lot easier for me to visualize things, if I close my eyes." After giving sufficient time for all to work through this activity, TP tries to engage the class through a discussion on what they had just done. [The class is only then reminded of this story about Laura who was blind. Laura also could not speak nor hear.]

(38)

TP: Before you take a look at what was in your bag, I would like one, a couple of you to talk about—Sean, I need you to pay attention—talk about what it felt like not to be able to see something but to have to feel it. And it's too bad that the room couldn't have been totally silent, then you would have the experience of not hearing or not seeing. Okay. Who can tell what that was like? Cathy.

Cathy: (It felt like being blind, I mean you are trying to figure out ...)

TP: Yeah, uh-huh. Okay. How did it make you feel? Have some feelings, Carol?

Carol: (((...) (I wanted to really see that ...)))

TP: Okay. Yeah, good. Andrew.

Andrew: (((...) (If I can feel what everything was, I knew what everything was because I touch them in everyday life.))

TP: Okay. What was the word you used?

Andrew: Mastered.

TP: You had mastered, felt like you had mastered the test.

Andrew: Yeah.

TP: And you knew what everything was.

Andrew: Uh-huh.

TP: So, this was not frightening for you at all.

Andrew: No.

TP: Okay. Kathy.

Kathy: It felt a little bit funny not being able to look and see what was in the bag, but I knew what it was because I see it just about everyday. (...
In (38) we find TP’s instructional intent which was to have her students “talk about what it felt like not to be able to see something but to have to feel it.” For Mary, TP was trying to get them to understand “what it feels like to be a blind person” [1-20-93]. The responses from Andrew and Kathy tell us that their prior knowledge or experience—whether it was visual or tactile—enabled them to know the items in the bag by just feeling them.

However, feeling an object can reveal more about it. I asked Cathy, Jody, Carol, and Mary whether feeling objects (such as cubes and pyramids) helped them to know these objects. Here are some of their responses [1-20-93].

(39)
Carol: [Holding and touching a pyramid] Well, I think it’s more better if you feel it because if you feel it you can get more of an idea—you can feel everything. Just seeing it, you can’t feel the texture [touching a face of a cube].

Mary: You can’t see how many sides if you just saw like a triangle [holding a pyramid], if she [TP] asked how many sides, you couldn’t. If you just saw a triangle on a paper but it was a pyramid you couldn’t really (tell how many sides it has).

Cathy: All you can do is look at it, you couldn’t feel it to see how it looked like.

Jody: Personally, for myself, I think it is easier to feel it than to see it.

14 Leushina (1991) points out that for small children visual and tactile experiences play a special role in the development of spatial abilities.

15 I had met with Mimi, a fifth grader, to find out her ways of visualizing a cube [1-26-93].

UT: You can’t see all sides, so how do you know it [cube] has six sides?
Mimi: Well, I know that if it was a square (then you would be able to see the top part). So, if there is a top part, there has to be a bottom part so it can sit on (or else it will fall through or something).

When I asked her if she was picturing a cube in her mind, Mimi pointed out that she was picturing all the sides—“I was kinda feeling it in my mind instead of with my hands.”
Mary: Yeah, but if you can't feel anything, Jody? If this was a point where you could not feel anything and everything was written down.

We find here that to feel an object enables these students to know about the object; simply seeing an object is not enough. Feeling engaged the students in the activity because that allowed them to create the "truth" about the geometric objects. This point is well illustrated in the quotation (used in the beginning of this section) from the book, *Women's Ways of Knowing*. Here the college students used their own powers of inference to create the "truth" about cubes. Feeling, then, provided these fourth grade students with confirmation or sense-making of the objects they were working with.

**Coming to know shapes in the math period**

TP introduces the chapter on geometry to her class by giving students on each table simple geometric shapes to work with [12-14-92]. There are 5 tables in the class and 4 to 5 students sit on each table. She begins by telling her class: "Look at some things that are similar. Look at things that are different about them." The classroom is noisy; yet, seems, full of excitement.

(40)

TP: Let's talk about some of the things that (...) you as a group found. *Talk about some of the things that you as a group found that were similar. Let's talk about some of the differences.* I want you to put all the shapes in the middle of the table. So, we don't have to hear it [Classroom chatter continues].

Okay, let's start with table 4. What kinds of things did you as a group find?

Erik: ((...) we found, we made a circle out of (...) little blocks, then we made.) I don't know. We really do nothing yet.
TP: Well, anyone else can add to that? What you found as similarities or differences, Anne?

Anne: Well, we tried, like usually you call it a square. Well, so, we call it a square usually, but we were looking for similarities and we looked and Nick found out that a square was if you looked at the square different way sometimes it's a cube.

TP: Okay, good. All right. How about table 5, what did you find?

Mary: We were discussing the cube.

TP: Okay.

Mary: Faces, how many faces it has.

TP: Oh, good. And what do you mean, what do you mean by faces?

Mary: (...the flat faces on the...)

TP: The flat side.

Mary: Yeah.

TP: Okay, great. You know, she just brought up something. If you turn (...) to page 266, you will see what Mary's talking about. There it shows you what a flat face looks like. Now, Mary, hold up that one like egg shape. (...) Could we say that has any flat faces on that particular shape? Andrew.

Andrew: (...)

TP: Diane, could we say that it has any flat shapes or flat faces?

Diane: (No.)

TP: No, if they are not flat, what would we call them? Barry.

Barry: You call it a sphere.

TP: Well, yeah, but what kind of, I am looking for what kind of round

Barry: Yeah, round or [Barry or another student says, curved] curved. Could we say it has a curved face on it?

TP: Okay. (...) So, we have flats and curved.

TP's instructions in the beginning of the activity allows the students to form their own meanings. TP's instructions to the class ("Talk about some of things that you as a group found that were similar. Let's talk about some of the differences") encourages the students to look for visual comparison among the geometric objects. Anne and Nick are able to perceive a relationship between a cube and a square ("if you looked at the square different way sometimes it's a cube") through a group discussion. TP's
interactions with Mary demonstrate her method of coaching so that the students are able to perceive that there are two kinds of faces: flat and curved.

TP frequently relates objects around in the classroom to the geometric figures which the students are learning about. Here in (41), for instance, we see an application of the “concept of visuality” in the classroom discussion (Antonovskii et al., 1991, p. 9). The kleenex box has a property of visuality because it reflects isomorphically the properties of a rectangular prism and is simple enough to be perceived by the students. Note that all geometric models here such as little/big cubes and pyramids demonstrate the property of visuality. TP’s intention here is just to show that the kleenex box is rectangular and not a square. This classroom instruction is possible as Carol was able to put her three cubes together and perceive a relationship between these “little” cubes and a picture of a rectangular prism.

(41)  
TP: You all look at page 266. Carol is talking about a rectangular prism. Okay, and she is saying that if you take these little shapes, you could have taken three of these small cubes, put them together and they would look like a rectangular—right here—prism. See that kleenex box. Okay, this kleenex box—look up here—this is rectangular. It is not a square but rectangular.

TP tries to discuss many geometric shapes and this often leads to a discussion on other concepts as we see in (42) the responses to TP's question, “what can we say about pyramids?”. Here Anne is able to perceive a two and three dimensional relationship between a triangle and a pyramid. This transcript also illustrates TP’s instructions of relating the
spelling of words to name the basic properties of geometric objects such as
“This is the vertex or vertices—you may want to make a plural, vertices.”

(42)
Anne: [Holding the pyramid] It is sort of like a triangle. It is shaped like a triangle.
TP: Okay, how is it different from a triangle?
Anne: Usually, a triangle has like, it's not as wide as this usually.
TP: Okay. Erik.
Erik: [Holding another pyramid] And it got four things and not three.
TP: What do you mean four things?
Erik: It got four sides.
TP: Oh. What's another name for those points, like look here. When two flat surfaces come together. See if you can find it on this page. What's the name for this part on page 266, anyone? It is on there somewhere. Erik.
Erik: (...) face.
TP: No, it is not, this is a face, but when two faces come together, they make a, Jody?
Jody: A vertex, a vertical.
TP: Well, a vertex is this corner piece. I am looking for the whole length.
Derek: (Curved edge.)
TP: You got it. I wished you would have raised your hand.
Erik: What is it?
TP: All right. Derek said, he said curved, but we are looking for edge. We are looking for the word edge. Okay. (...) This would be considered a straight edge. (...) Where is, Anne, show us the vertex, show us one vertex on your pyramid [Anne points at a vertex on the base of her pyramid]. Look at all the new words we are learning. Good list for spelling. So, you know what, how many of you passed all spelling (...) words. How many of you need words for your spelling test? A few of you. If you need words, right here they are. Many words. Okay. So, now we got... This is the vertex or vertices—you may want to make a plural, vertices. We have an edge; boy, we have learned a lot here, edge. This is a flat, what?
Erik: Face.
TP: Flat face and some of you had a curved face.
TP, often, provides the class an opportunity to make their own definition of the concepts they are learning; for instance, a vertex is a corner. In (43) we also see a simple example of an IRE sequence: initiation from the teacher followed by a response from the student, which in turn is followed by an evaluation of this response from the teacher (Mehan, 1979). However, the teacher evaluation of the response here is based on "stretching and sharing" a student's perspective to the class (Belenky et al., 1986, p. 223).

(43)
TP: You know, I never really gave you a definition for vertices. What do you think our definition should be for vertices? What do you think it should be? Carol.
Carol: A corner.
TP: That's pretty good, it's a corner. Could we say it's where
Mary: (Where edges meet.) [softly]
TP: straight, go ahead Mary.
Mary: Where edges meet.
TP: Okay, where straight edges meet.

TP ends this math period with a class activity with the following instructions. We see in (44) TP's attempt to relate objects from students' everyday life to geometric shapes. As in (41), we also see here the application of the concept of visuality since both the teacher's cup and a package of crayons have the property of visuality. It is to note, for instance, that the cup is "partially isomorphic" (i.e., partial reflection of the properties of a cylinder), but as the students get acquainted with these geometric shapes the cup becomes a "complete isomorphism" (Antonovskii et al., 1991, p. 11).

(44)
TP: I want you to think about some shapes that you see in everyday life. Of course, you don't walk around and see pyramids outside [There is a brief laughter in the class].
But, I want you to think of shapes from your everyday life. Maybe this cup on my desk—you see this enough. Tell me what kind of, write down, you can put down: teacher's cup, and then say

Sean: cylinder
TP: cylinder. Maybe you can write down package of crayons, say rectangular

Sean: prism [Another student also says it]
TP: You know what I want. I want at least ten objects written down on your paper. I want it to be soft, I want you to discuss this quietly, and then every person will be responsible for making their own list.

[Mary's list:
1. Disk drive - rectangular prism
2. Waste basket - cylinder
3. Table - hexagon
4. Shelf - rectangular prism
5. Globe - sphere
6. Book - rectangular prism
7. Eraser - rectangular prism
8. T.V. - rectangular prism
9. Quarter - has 2 flat sides
10. Ruler - rectangular prism]

When I asked Mary, Jody, and Cathy how many sides does a rectangular prism have? Jody said that it has four sides while Mary responded with 6 sides. Cathy asked: "Are you counting the sides that we can see, just the sides we can see?" [1-20-93]. Only when I said that I meant all sides, did Jody and Cathy respond with the correct answer: six sides. The students, then, had to visualize the two hidden sides of the prism; for instance, only four sides were directly visible to Jody.

**Instructions to discover shapes in the math period**

The next day [12-15-92], TP continues on with this chapter on geometry. She leads the class through the concept that planes are flat, i.e., two-dimensional pieces. In (45) we find that TP directs her students to use both
two-dimensional and three-dimensional representations. Students also develop their own meanings—for Erik a plane is a flat ground. For Carol a square is a flat cube [1-20-93]. Yakimanskaya (1991) points out that “children recognize spatial properties of things and events largely by identifying relations of order, i.e., through the disposition of objects relative to each other, identification of their shape, and analysis of the features of this shape” (p. 132).

(45)  
TP: Who can tell me, what we did in art class not too many days ago? What were we doing, when you did these [Holding a student’s model]. What were we doing here? What were we doing?  
Erik: (Flat.)  
TP: Erik.  
Erik: A plane.  
TP: Yeah, we were doing some planes. And, Erik, can you tell me what makes up a plane?  
Erik: A flat ground, a flat surface.  
TP: A flat surface and we had a lot flat surfaces in this one, didn’t we? Okay. Great. Did we have any spheres in here?  
Class: No. [softly]  
TP: No. Any cylinders?  
Class: No.  
TP: Okay, they were basically just two-dimensional pieces, weren’t they? They were flat. Let’s take a look at page 268. There you see a picture of a cube. Now, we didn’t use cubes, did we? We just used the flat surface of a cube which we could call a what? Jeff, what was that?  
Jeff: A square.  
TP: A square. Good. And that’s what they show you right there on that picture. They have a rectangular prism beside that. What plane figure—plane [spells the word]—is beside that?  
Carol: A rectangle. [softly]  
TP: Good. A rectangle. Do you see the corner, Erik and Derek, of the rectangle? See where they show you that is the vertex—where those two lines intersect there—they come to a point. Okay, let’s look at the cylinder. What would be the plane figure of the cylinder? Derek.
Derek: Circle.
TP: Yeah, a circle. Now, what about the triangle?
[Someone says (you are suppose to say what about a pyramid.)]
TP: I am sorry. I gave it away, didn’t I?

In (46) TP begins to provide instructions for a task using the geometric shapes. TP provides coaching on this task by illustrating first on the board [see Figure 25]. The purpose of this task is “to discover how many different kinds of shapes” the students can make in “any kind of design.” Carol, for instance, used colors in her design. She used over-lapping technique on her design so that, for instance, red and yellow circles over-lapped to make orange color in the intersection.

(46) TP: I am going to give you a plain piece of paper. Now you can make this as colorful or as plain. Some of you, if you like shading, if you like different radiance of gray, if you like different shades of gray, you can just use your pencil, you can make some shapes really dark, some shapes not so dark. I am going to give each of you a piece of paper, and I am going to give your table (just listen) I am going to give your table some of the shapes that we used yesterday. Now in our class, we have done a lot with over-lapping, haven’t we? I want you to make a design.
(…) [Her instructions continue]
Now, yesterday, we had a little difficulty. I was greatly surprised at how you treated those shapes. Today, I’d like to see you do it a little bit better. Okay. That means waiting for somebody to finish, being patient, what could you be doing while you are waiting for a shape? Sean.
Sean: You could be designing your paper (in your head.)
TP: Yeah. You could be designing your paper more in your head. Erik.
Erik: Think about something.
TP: Sure. Okay. (…) I want everyone listening. You may take any shape and let’s really show each other that if David really would like to use this shape [holding an object] and it is over on table 5, he can walk over and he can say “when
you are finished with that shape would you bring it over to my table." And yes, we should be able to do that.

(...) [TP now draws on a piece of paper that is stuck on the blackboard in front of the class.]

What I want you to do is to take your shapes, trace around them, and make some kind of—any kind of—design you want on your paper, and then you may decide if you just want to use a pencil and fill in a dark gray like that versus like a lighter gray. Fill in a lighter gray. Or—you are not using markers for this—(...) if you want to use...

[Someone says colored pencils. TP continues to work.] colored pencils that you could do. Now, look here. Here's something that you should be discovering. I don't have the shape here for a triangle, but if I use part of this piece, and then I line it up here—I get a ruler, flat edge—I can make a base line of my triangle. So, even though you don't have a triangle shape, you can figure out how you can make that shape. What I want you to do is I want you to discover how many different kinds of shapes you can make, and I want you to work as far as sharing shapes.

Figure 25. "Now, look here."
TP's example of making a base line of triangle using a pyramid (with a flat top) demonstrated the discovery nature of this task ("So, even though you don't have a triangle shape, you can figure out how you can make that shape. ... I want you to discover how many different kinds of shapes you can make"). When I asked Mary if her shapes meant anything, she said that she "was just making things out of them." TP went around the class looking at everyone's work and gave more instructions.

(47)
TP: Folks, I guess (...) I failed to mention. We don't want any free-hand shapes, these are only shapes on your paper that you have traced—only shapes that are from these objects, like you are not drawing a palm tree or something. (...) I guess you can draw a palm tree if you have the right shapes for it.

Student: (I can make a palm tree.)
TP: (It will be like creative for you ... )
(...) [TP walks around all tables, looking at students' works and displaying them to the rest of the class.]
Look at how interesting this one is. David's used all circles. Okay, and then look at Diane's. She's used lot of triangles—table 1 look up here—she's used triangles, rectangles, and squares. Very nice. Dan has an interesting idea of putting one square inside of another. And Erik has a really good idea of actually making a person with shapes.

From (46) and (47) we see that TP's set of instructions for this task not only guides actions but also encourages and therefore generates discovery. Erik, for instance, is able to draw a figure of a person using only the geometric shapes, and thus creates his own representation of a person. Arnheim (1969) suggests that making "a picture of a human figure or a bunch of flowers is to grasp or invent a generic form pattern or structural
skeleton. This sort of practice is a powerful aid in establishing perceptual basis of cognitive functioning" (p. 295).

"You need lines in almost everything you do"

TP had previously discussed in class the lines and patterns made by the Nasca Indians of southern Peru during the period between 500 BC and 500 AD. The classroom resource was a chapter, "Nasca: The patterns of Peru" from the book, *The Atlas of Mysterious Places*. During a lunch interview, Mary and Cathy described to me how they studied right angles from the Nasca inscriptions [1-20-93]. From the Nasca figure of a hummingbird in the atlas, Cathy showed me how this figure made a right angle with a straight line. Cathy then demonstrated her understanding of a right angle on the board [see Figure 26]. Here is some of what she and Mary said while drawing on the board.

(48)

Cathy: If you can have the edge of your paper or the edge of something [she is holding a chalk eraser] and fit it right in here then that is going to be a right angle.

Mary: The edge of a ruler is 90°. (…) look at this) if it can fit up in there and you know that’s a right angle because a right angle is 90°.

From the study of Nasca inscriptions, the students are able to identify patterns such as right angles within a two-dimensional system, and then are able to transform their understanding through a three-dimensional system; i.e., using the objects in class.
Millman and Speranza (1991) suggest that teachers should use works of visual arts in class to aid in their students' understanding of geometry concepts by making them less abstract. For these fourth grade students, with the study of the Nasca patterns, geometry ideas such as right angles and lines can be found everywhere and in everything they do. Mary draws a square on the board and says "when you make a square, you have to have lines". And Cathy responds with "so you need lines in almost everything you do. I mean for, like, for a $d$ or $b$." Carol draws a shirt on the board using lines. The study of Nasca Indians not only exposed the students to the Nasca history and social life, but more importantly made them comfortable with geometric ideas.
We find here that visualization can be viewed as a set of practices which take place in the classroom contexts where the participants frequently create their own meanings and make their own discoveries. In TP's classroom, we find that students seem to develop visual-spatial relationships of objects in the classroom by drawing upon their everyday experiences and observations. TP's instructions to her students are generative in that they are built on students' ongoing sense-making. TP facilitates an environment in which it is natural for the students to think visually.
MYSTERY POWDERS

The entire nervous system interacts with sight, enhancing our ability to discriminate. Touch, taste, hearing, smelling, all contribute to our comprehension of the world around us, augmenting and, sometimes, contradicting what our eyes tell us. We touch something to determine if it is soft or hard; we smell something to discover if it is fragrant; we taste something to find if its pleasant odor indicates that it is equally pleasant to eat; and we listen to know if something is moving or still. All our senses are discriminating and constantly refining our recognition and understanding of the environment. But, of all our senses, there is little argument that the one we depend on the most, the one that has superior power, is sight. (Dondis, 1974, p. 88)

In this section, I provide descriptions of visualizations that occur in one fourth grade classroom during a science unit. Ms. Trisha Miller (TM), the classroom teacher, taught a unit on mystery powders in six class periods. TM likes to teach science to her students by allowing them to do experiments and to see the process (of simple reactions) themselves. Students worked in groups of two and each group was given five powders whose identity the groups first had to find. Her instructions were on the board: 1) Put a little of each powder on black paper, 2) Observe—use magnifier, 3) Draw/color, 4) Write properties, and 5) When finished throw black paper and staple other paper together—hand in. TM told her students that they could taste, smell, feel, look, and hear the powders (which were given in cups) to find out their properties. TM had modified this science unit on chemistry to include the drawing of the powders so that the students may come to really

16 I made audio recordings of the parts of the first and second sessions and video recordings of parts of the remaining sessions. The audio in the fifth session was accidentally not done.
see the powders. TM told me (based on her reading of the book *The Zen of Seeing* by F. Franck): "if you want someone to look at something, have them draw it" [1-27-93]. Jill pointed that tasting and touching the powders worked along with looking at them through the magnifying glass "because then you can sort of tell what it is" [1-14-93].

The five powders (see Figure 27) that the students received were: salt (A), baking soda (B), corn starch (C), sugar (D), and plaster of paris (E). I worked with Jill and Cindy. TM pointed out that this year she and two other fourth grade teachers were "having kids draw things before they would actually write down anything about it. And it really seem to help because this was the best... I have done this three years now and this is definitely the best writing that they did about it ever and I think that the drawing really helped and I didn't know ... if they are going to be able to draw it or not, but most of the kids really came up with some way so that they could look at that again and see what they were trying to draw" [1-27-93]. Drawing the powders as well as looking at them through the illuminated microscope and magnifying glass allowed the students to compare what they were seeing to what they already knew. For instance, Cindy said that baking soda (through the microscope) "looks like a whole bunch of icicles" [1-14-93].
<table>
<thead>
<tr>
<th></th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1. Medium crystals</td>
</tr>
<tr>
<td></td>
<td>2. Some was gray</td>
</tr>
<tr>
<td></td>
<td>3. It's sour</td>
</tr>
<tr>
<td>B</td>
<td>1. It has little crystals</td>
</tr>
<tr>
<td></td>
<td>2. Looks powdery</td>
</tr>
<tr>
<td></td>
<td>3. It is a little white</td>
</tr>
<tr>
<td>C</td>
<td>1. It looks like fluffy snow</td>
</tr>
<tr>
<td></td>
<td>2. It does not have crystals at all</td>
</tr>
<tr>
<td></td>
<td>3. It's easy to get it all stuck together</td>
</tr>
<tr>
<td>D</td>
<td>1. The biggest crystals</td>
</tr>
<tr>
<td></td>
<td>2. It's sweet</td>
</tr>
<tr>
<td></td>
<td>3. It does not become gray</td>
</tr>
<tr>
<td>E</td>
<td>1. It's like snow lying there</td>
</tr>
<tr>
<td></td>
<td>2. It's grayer than the rest</td>
</tr>
<tr>
<td></td>
<td>3. You can draw with it</td>
</tr>
</tbody>
</table>

Figure 27. Jill's powder properties.

Jill and Cindy on their drawings made a gray boundary around salt (powder A) after looking at it through the illuminated microscope. Most of the groups, including that of Jill and Cindy, were able to identify salt, baking soda, and sugar. They also noted down that these three powders had crystals of different kinds: medium, little, and big. Cindy after looking through the microscope noted that the crystals in salt were more square than those in sugar [1-14-93]. Alice also made a similar observation [1-21-93].

Next the students had to add water (few drops, 20 drops, 50 drops, and 80 drops) to the powders and noted down their observations. Jill after adding 80 drops of water in salt pointed out that the water “is mixed in but you can still see the crystals [referring to the observations of the first day].” Jill also found that after adding 80 drops of water in sugar it became “a clear
"water" and was more clearer than salt. The students were not only seeing the process (i.e., simple reactions) but also learning to record their observations. The students seem to enjoy doing this experiment. The class was full of conversation.

In another period, TM told the class what the five powders were since most of the groups could not figure out powder C (corn starch) and powder E (plaster of paris). Many students were also able identify powder B (baking soda) by tasting it. TM provided further instructions for the next task [1-20-93].

(49) TM: You have two sheets. The first sheet is day 2 of water. So, you going to write the powder name and what happened to it overnight, or (...) I should say what does it look like this morning when you looked at it. And, then, the second page is: put the powder name and then what happens (to it) when you add vinegar. You need to look closely (...) so that you can describe how it changes if you add the vinegar.
<table>
<thead>
<tr>
<th>Powder Name</th>
<th>What happened when left overnight, mixed with water</th>
<th>Powder Name</th>
<th>What happens with vinegar?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>You can still see the salt but it is still watery</td>
<td>Salt</td>
<td>All got crunch together but is still wet</td>
</tr>
<tr>
<td>Baking soda</td>
<td>Disintegrated in to water</td>
<td>Baking soda</td>
<td>Fizzed and got softer</td>
</tr>
<tr>
<td>Corn starch</td>
<td>Like butter milk</td>
<td>Corn starch</td>
<td>Hardened and turned yellow</td>
</tr>
<tr>
<td>Sugar</td>
<td>Disintegrated in to water but was clearer than baking soda</td>
<td>Sugar</td>
<td>You can see through it</td>
</tr>
<tr>
<td>Plaster of Paris</td>
<td>Dry clay or plaster of paris</td>
<td>Plaster of Paris</td>
<td>Fizzed and hardened and was darker</td>
</tr>
</tbody>
</table>

Figure 28. Jill's observation sheets.
While Jill could compare baking soda and sugar to find out the effect of water on the powders overnight by simply looking into the cups, she had to touch plaster of paris—"It's dry. It's not wet, I could feel it." The vinegar test illustrates the discovery nature of this unit. For instance, let us look at the parts of the baking soda and plaster of paris transcripts as Jill compares the two powders.

(50)
Jill: Look it bubbled, did you see that? [adding first drop]
UT: (Yeah.)
Jill: (It fizzed.) [adding second drop]
UT: What is it?
Jill: It fizzed.
UT: Fizzed.
Jill: [nodding and touching baking soda] It got soft.

When I asked Jill what she meant by fizzed, she replied that it is like "when you have a soda, you open it and pour it in glass, it fizzes." Both powders—baking soda and plaster of paris—bubbled (fizzed), but Jill was quick to point out the difference to me: "this one got softer and, then, this one got harder when it fizzed."

(51)
Jill: It fizzed. [after adding vinegar]
UT: Yeah, but like... [pointing to baking soda]
Jill: No, this one mainly bubbled.
UT: Right.
Jill: (...) and it hardened... It hardened. (It's harder than the soft kind.)

TM also tries to lead her students through examples by discussing with them before the experiment. This is well illustrated in (52) where the students are to work with a mixture of two powders.
You put iodine on it [mixture] and it turned black. What do you think one of the powders is, probably? Alice.

Alice: Corn starch.

TM: Corn starch, probably. Now, what about, if it turned black, but you know there's two powders in it, then do you know yet what the other powder is? Mike.

Mike: [Nods.]

TM: No. So, then, you need to do (another test.) So, let's say you did iodine and it turned black and then, let's say, you did vinegar and it doesn't bubble. So, what powder do you think isn't in there? What powder (...)? Jan.

Jan: Plaster of paris.

TM: Okay, plaster of paris, probably would be one that isn't. Tina, what would be (other one)?

Tina: (Salt.) [softly]

TM: Salt, salt shouldn't bubble. So, if it doesn't bubble then it might have salt in there. Alice.

Alice: Baking soda.

TM: Baking soda.

[...]

TM suggested to her students to use information from the previous tests for filling up the observation sheets columns. Jill, for instance, went back to her vinegar test to check (see Figure 28) and then wrote down "hardened and turned yellow" on her Test #4 (see Figure 29) as she guessed that corn starch could be one of the two powders in the mixture. In second mixture, Jill and Cindy immediately concluded that the mixture is composed of plaster of paris and baking soda as it fizzed on the addition of vinegar (see Figure 30). Again, they referred to their vinegar test and found that only these two powders fizzed when vinegar was put on them. Also, see (51) and (52).

However, they put corn starch on Test #3 under the Powders it might be column since the mixture looked powdery through the microscope and corn starch is powdery or like fluffy snow (see Figure 27).
| Test #   | What are you looking for? | What do you observe? | Powders it might be | Powders it couldn't be  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Test # 1 Taste</td>
<td>Like corn starch</td>
<td>sugary corn starch</td>
<td>sugar, corn starch</td>
<td>salt, plaster of paris, baking soda</td>
</tr>
<tr>
<td>Test # 2 Iodine</td>
<td>Turns black</td>
<td>Fizzed</td>
<td>corn starch, plaster of paris, baking soda</td>
<td>salt, sugar</td>
</tr>
<tr>
<td>Test # 3 Looking</td>
<td>Powdery with little crystals</td>
<td>Powdery with little crystals</td>
<td>sugar, corn starch, salt</td>
<td>plaster of paris, baking soda</td>
</tr>
<tr>
<td>Test # 4 Vinegar</td>
<td>Hardened and turned yellow</td>
<td>Hardened and you could see through it</td>
<td>sugar, corn starch</td>
<td>plaster of paris, salt, baking soda</td>
</tr>
</tbody>
</table>

What powders do you think it is? Corn starch and sugar.
Explain: Almost every time that's what it came to.

Figure 29. Jill's observation sheets for mixture identification.
**Mystery Powder Mixture Identification**

**Mixture symbol △**

<table>
<thead>
<tr>
<th>Test #</th>
<th>What are you looking for?</th>
<th>What do you observe?</th>
<th>Powders it might be</th>
<th>Powders it couldn't be</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test # 1</td>
<td>Fizz</td>
<td>Fizz a lot</td>
<td>plaster of paris, baking soda</td>
<td>salt, sugar, corn starch</td>
</tr>
<tr>
<td>Vinegar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test # 2</td>
<td>Yuck!</td>
<td>Yuck!</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Taste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test # 3</td>
<td>Very powdery</td>
<td>Powdery</td>
<td>corn starch, plaster of paris, baking soda</td>
<td>salt, sugar</td>
</tr>
<tr>
<td>Look</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test # 4</td>
<td>Hardened</td>
<td>Hardened</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What powders do you think it is? Plaster of paris and baking soda.

Explain: Everyone describes it.

Figure 30. Jill's observation sheets for mixture identification.
In the mystery powder unit, we find that the students are learning about these powders by doing simple experiments. Drawing, looking/seeing (directly or through a microscope), touching, and tasting the powders are all part of this science unit on chemistry. The visual experience was more than seeing the powders. Using the microscope helped the students know more about the powders ("It has little crystals"). While looking closely was important, so was touching ("It's harder than the soft kind") and tasting ("sugary corn starch"). Students recorded their own observations partly through discovery ("It fizzed") and partly through their prior experience as illustrated here.

(53)
UT: Do you like this experiment?
Jill: [Nods.]
UT: Why do you like it?
Jill: Because it's fun. You kinda had, not now, but you kinda had to guess what it was and [for] most people it was like a give away (...) when you tasted the salt and the sugar. But, I like (...) looking at them closer and studying them (...).
DISCUSSION

Visual thinking is indivisible: unless it is given its due in every field of teaching and learning, it cannot work well in any field. The best intentions of the biology teacher will be hampered by half-ready minds if the mathematics teacher is not applying the same principles. We need nothing less than a change of basic attitude in all teaching. Until then, those who happen to see the light will do their best to get the ball rolling. Seeing the light and rolling the ball are good visual images. (Arnheim, 1986, p. 151)

Bishop (1989) recommended that the study of visualization process—the how of visualizing—be conducted in a variety of educative settings. Such studies would enhance our understanding of the visualization process. Presmeg (1992) suggests that increased awareness of the usage of visual imagery in mathematics classrooms would help in teaching and learning. Nakaji (1991), who studied visualization in physics classrooms, reports that his students "identified a wide variety of uses for visualization, from checking and clarifying elements of the problem to identifying relationships and understanding interactions" (p. 84). Most researchers, such as Bishop (1989), agree that visualization is very personal since different people may process an image in different ways.

These descriptions demonstrate the work of visualizations in these classrooms by my participants in different ways. What counts as visualization is mediated through interactions among the participants in classroom contexts. Through their instructions, the teachers facilitate an environment in which it is natural for the students to think visually. The students begin to develop a situated sense of visualizing organized by these classroom instructions. The students create their own discoveries and make
their own meanings. The processes of visualization in the classrooms becomes visible by these interactions. Everyday activities in the classrooms represent situated practices of what students and teachers do everyday (Lave, 1988; Lave, Smith, and Butler, 1988). These data descriptions reveal the visualization practices of the teachers and students in these three classrooms everyday. The transcripts and descriptions conveyed what is generally occurring in these classrooms. So, in this sense these classroom events are "general, reliable and repeatable" (Brown, 1992, p. 173). I summarize these data descriptions now by answering the general research questions for each of the three classrooms.

**Trudy Parker’s fourth grade classroom**

The students work with geometric shapes such as cubes and pyramids and through their activities they make sense of these objects ("we call it a square usually, but we were looking for similarities and we looked and Nick found out that a square was if you looked at the square different way sometimes it's a cube"). Students are given tasks to relate what they are learning in geometry to what they see everyday ("I want you to think of shapes from your everyday life"). Mary found that the table top she is working on is shaped like a hexagon.

TP provides visual and tactile understanding to her students. Carol likes to feel (touch) geometric objects such as cubes because by "[just seeing it, you can't feel the texture." TP also encourages her students to form their own perspectives ("Let's talk about some of the differences"). She, often, demonstrates to her students step by step a concept or an idea ("Now, look
here. Here's something that you should be discovering. I don't have the shape here for a triangle, but if I use part of this piece, and then I line it up here—I get a ruler, flat edge—I can make a base line of my triangle”). TP also tries to engage her students in visual activities in subjects other than mathematics. In a reading period, TP provides verbal directives (“What you are going to do is without looking—now this is going to be challenging—you are going to put your hand in a bag. Now, if I were you it is a lot easier for me to visualize things, if I close my eyes”) so that her students can understand, as Mary pointed out, “what it feels like to be a blind person.” TP also works with MB to infuse the visual arts into her classroom curriculum. Students, through their study of the patterns by Nasca Indians of southern Peru, learned that geometric ideas such as right angles and lines can be found everywhere and in everything they do.

**Trisha Miller's fourth grade classroom**

The students do simple chemistry experiments themselves so that they can see the process of simple reactions such as what happens if one adds a drop or two of vinegar to a sample of baking soda. Jill likes to look at the powders under a microscope so that she can study them closely. The students record what they see while comparing to what they already know (“It looks like fluffy snow”). The visual experience is achieved also through the use of other senses such as touch (“It's harder than the soft kind”).

TM included an exercise of drawing the powders in this chemistry unit. This, she contends, allowed them to really see the powders since seeing and drawing now work together in an activity. TM provides verbal directives
to lead her students through sample experiments ("You put iodine on it and it turned black. What do you think one of the powders is, probably?").

**Peter Hart's fifth grade classroom**

Students are primarily given set of instructions through a lecture format in PH's classroom. Students learn to externalize their thoughts in visual arts period while making Dali like pictures. As Emma pointed out: "you can take your dream and your thoughts and put it in on a piece of paper in his style but not like his work or his things like that." Students demonstrate their understanding of the colonial America through role-playing in social studies. Students are often asked in class to think imaginatively and to visualize ideas. Sam, when asked by PH to use imagination in class, is led to think about making "different images of one thing depending on what you [are] doing and make the best thing that would work for that."

PH makes simple diagrams ("scribbling little drawings, cartoon figures") on the blackboard so that his students can understand the basic concepts of astronomy and electricity he is trying to teach in science. These diagrams are drawn and redrawn as he instructs. PH's verbal directives guide his students what to see on the board ("But, you can imagine the sun stable at this point. The earth as it goes around, the moon is also going to be going around the sun. So, these three things are going to continue to change in relationship to each other, okay, as they go around"). Jean was able to understand how the short circuit works because when PH draws on the board "he shows you where and how." PH tries to invoke images in his students' minds. Gestures, analogies ("The solar system has the sun in the
middle and has stuff flying around it. So do atoms”), and descriptive language (“We will call that little thing earth”) are generated in activity.

In the chess club, however, his instructions to his students organize their ways of visualizing the chess situations. He does this by providing scaffolding and shaping. Scaffolding is “the teacher’s selective intervention [that] provides a supportive tool for the learner, which extends his or her skills, thereby allowing the learner to successfully accomplish a task not otherwise possible” (Greenfield, 1984, p. 118). Shaping, on the other hand, “involves a series of successive approximations to the ultimate task goal” (Greenfield, 1984, p. 119). In PH’s chess lessons, the ultimate task goal is, usually, to checkmate the king or to look for a tactic (e.g., discovered attack). While this task is held constant, PH simplifies it by giving verbal and gestural directives. Such interactions usually help the new members so that they can start to “visualize more of the game and visualize more moves ahead.”

PH often employs seeing as an instructional device organized by questions/answers [see, for instance, (6)]. Through his verbal directives, the students are led to see a skewer and then reminded about its comparison to a pin. PH also organizes, reorganizes chess pieces on the illustration board. This happens when he is trying to relate different chess situations. As the board is re-configured to meet the next situation, we find that not all pieces of the new configuration are present on the board. The board is often left incomplete. The students are invited to imagine pieces and their supposed movements on the board. In (9), for instance, PH only has a white rook on h1. Rest of the pieces on the board are from a previous situation [see (8)]. The students are called upon to perceive that the white queen
represents the white bishop. The position of PH's black queen on the board is not mentioned—it could be anywhere. But, the students have to imagine it being on a square where it can be attacked by Carl's white bishop.

(9)

PH: What Carl did to me basically was this idea right here. He had a bishop where the queen is and his bishop came and took this pawn [h7] and checked me. I had to move here [h8] and he moved his bishop out of the way which checks me discovered [directing the path of the rook on h1]. And his bishop went over and attacked my queen. I could not do a thing about it.

The chess descriptions demonstrate how visual representations are created in activity not cut off from it. As PH said: “it's hard to know what goes on in the mind.” When the students begin to use chess tactics in games he comes to know that his lessons are working (“The lesson for today, folks, is to plan ahead, have ideas and reasons because you can start pulling this kind of stuff on me. What Carl did to me basically was this idea right here”). Students are encouraged to use their imagination. Matt's chess image of a castle allows him to visualize a chess move in his head. For Matt, seeing and doing work together. This provides him with the understanding of what he is doing, why does he need to do it, and how can he do it.

PH's teaching practice facilitates thinking visually in his classroom. He uses techniques such as diagramming sentences (even though this is not recommended in the school curriculum) because diagramming allows his students to visually comprehend the sentence structure. PH also guides his students to be responsible (“I am your teacher, I can help you. But, you got to help yourself by looking at this work”). Students then tend to develop a
situated sense of visualizing in the classrooms organized through PH's instructions.
Chapter V

SUMMARY, DISCUSSION AND IMPLICATIONS

This study documents everyday visualization processes in classrooms to enhance our understanding of the visualization processes in education. Everyday visualization is about a participant's actions—interactions with the environment—situated in a classroom context. The participants begin to develop a situated sense of visualizing as they learn to perceive, understand, create, and express through images: visual, auditory, and kinesthetic. The study of visualization processes in everyday classroom contexts reveals different ways of visualizing by students and teachers. The data descriptions in this study conveyed what was generally found to occur in these classrooms. The use of qualitative methodology allowed the researcher to describe and understand visualization processes used by students and teachers in the classrooms. Understanding everyday visualization should help in the design and development of effective instruction in classrooms.
SUMMARY

The purpose of this study was determined (as discussed in Chapters 1 and 2) after reviewing the visualization literature and finding that the everyday practice of visualization in classrooms had not been extensively studied. Furthermore, it was also realized that psychometric tests were not suitable to study visualization processes embedded in everyday classroom activities. A qualitative approach was then used. The unprespecified nature of this approach allowed the researcher to study processes of visualization in various instructional contexts. The purpose and methodology of the study are now summarized.

Purpose. The purpose of this study was to explore, describe, and understand the phenomena of everyday visualization in elementary classrooms. To attain this purpose, visualization processes embedded in everyday classroom activities were studied. This investigation then provided the researcher with understanding of everyday visualization practices in classrooms.

Methodology. A qualitative approach was used to understand visualization in the classrooms everyday. Participant observation was one of the major sources for data gathering. Data was collected in forms of audio and video tapes, field notes, informal interviews, and classroom documents. Validity guidelines offered by Lather (1986a) were followed to give credibility to this study. The researcher worked together with the researched. This provided
the teacher participants to become familiar of the research process as well as develop an understanding of the visualization process.

**DISCUSSION**

**Visualization in everyday classroom activity**

The data descriptions in this study show that visualization is an everyday practice in classrooms. School activities such as playing chess (which is generally not encountered as an everyday practice in most elementary schools) is part of a daily routine for many students in this Arts IMPACT school.\textsuperscript{17} The curriculum in the chess club resembles a “learning curriculum” because the curriculum evolves out of the everyday practice as opposed to a “teaching curriculum” where instruction is primarily transmitted by an external view (Lave and Wenger, 1991, p. 97). The students who are in the chess club play chess during lunch periods everyday. In the science periods, Mr. Peter Hart (PH) makes everyday use of simple visual representations to facilitate the understanding of his students. Activities such as diagramming sentences and role-playing in PH’s classroom do not occur on a daily basis. PH uses role-playing if it can be tied to the subject matter and provided the students show interest. During the early part of the first semester, PH used diagramming as a visual tool for teaching grammar to his students. The classroom activity observed in two fourth grade classrooms focused mainly on everyday classroom workings in a few math

\textsuperscript{17} L. B. Cullman, chairman of the American Chess Foundation, mentioned in a letter (Learning by Chess, June 21, 1993) to *The New York Times* that introducing chess in New York City Public Schools brought about improvements in the reading skills of the students. The data descriptions of the chess club in this elementary school reveal how instructions organized the ways of visualizing of the students.
and science periods. Both teachers encouraged their students to create their own meanings and make their own discoveries. Visual thinking was also facilitated in these classrooms through "dialogue and interaction" between the participants within the context of classroom curriculum (Belenky, Clinchy, Goldberger, and Tarule, 1986, p. 18).

Research on visualization has traditionally been conducted through testing and training procedures without examining the interaction of the participant with the context of classroom activity. Integration of visual-spatial activities in schools has been suggested by many researchers (e.g., Baker and Belland, 1986). Bishop (1989) pointed out that the psychometric approach may not be appropriate for the study of visualization processes and recommended further research on the visualization process in a variety of educational settings. Yakimanskaya (1991) recommended qualitative research to study spatial thinking among school children.

Lave and her colleagues (Lave, Smith, and Butler, 1988; Lave, 1990), who studied mathematics practice in children's classroom everyday, have suggested that it is worthwhile to analyze the situated practices of classrooms. Harley, who studied how third and fourth grade students did math word problems, also argued that the classroom as a setting must be understood in its own terms since the students are thinking situationally depending on various instructional contexts (Harley, 1991). Understanding of the everyday practices in school classrooms provides us with the knowledge of what is being learned and how it is being learned. Scribner, Gauvain, and Fahrmeier (1984) observed product assemblers filling dairy orders in the warehouse (see Scribner, 1984a). Through their analysis of
the goal directed actions (such as assembling items listed on an order form) in the warehouse, they found that the workers used their spatial knowledge of the warehouse to organize their work. In classrooms, just as in a warehouse, one finds goal directed actions (such as Mrs. Mona Ball (MB)) demonstrating a Dali like background by drawing it while eliciting ideas from her students or PH demonstrating a sequence of moves of the white chess pieces to checkmate the black king). The analysis of such goal directed action allows us to understand the visualization process—the how of visualizing—embedded in everyday classroom activity.

**Instruction to visualize in the classrooms**

The study provides glimpses of the instructional practices of the teachers with regard to their emphasis on visualization in classrooms. The teachers organized the visualizing processes of the students through their instructional practices. PH, for instance, provided didactic instruction for the most part. Ms. Trudy Parker's (TP) instruction, on the other hand, is generative in nature in that she tried to relate the geometric concepts to students' everyday experiences and observations. Students created all sorts of images and ideas (e.g., Mimi's visual-kinesthetic image of a cube). The practice of visualizing by the students is developed through classroom activities (e.g., discussion on astronomy pointillism). Representations are also created through gestures and analogies and sometimes without actual drawing or illustrating on the board. The students then developed a situated sense of visualizing as these representations are created/recreated and given meaning in activity (Clancey and Roschelle, 1991). Wileman (1993)
points out that visualization as a process must aid in conceptualization of the material. For instance, PH's illustrations on workings of the short circuit aided its conceptualization for Jean ("if he draws he shows you where and how"). The data descriptions are now summarized.

*Pawns from the Dungeon.* The school chess club may be thought of as a "community of practice" (Lave, 1990) where all students interested in chess participate to collect experiential knowledge and the skills necessary to "see" things on the chess board so that they can win more games. Students learn to play chess using notation sheets and time clocks to become more skilled in chess playing. Students in the club learn to see the chess pieces relative to each other on the chess board through instructions as PH provides scaffolding and shaping (Greenfield, 1984). Visualization in the club is organized through verbal and nonverbal interactions so that the students learn not only to interpret spatial images but also create their own (e.g., Matt's dynamic chess image of a castle). The descriptions of these interactions demonstrate how visual representations are created within the chess lesson activity. Students are led to see the chess moves which are created through gestures by pointing at imaginary pieces and also by reorganizing of the chess pieces on the illustration board.

*TP's classroom.* TP provides visual and tactile understanding in the class by encouraging her students to develop their own meanings and make their own discoveries. She also engages her students in classroom discussions. So, students are not just receiving knowledge about geometric concepts.
from her; instead, they are making sense of geometric figures and shapes through these activities and discussions. TP's instructional practice guides actions of her students, demonstrates tasks for them, and encourages their discovery learning. Edgar Dale has written on learning as a product-process (what-how) relationship. Dale (1972) argued that this relationship "is directly related to knowing. In one sense to know is to have knowledge of (a product). In another sense it means coming-to-know (process)" (p. 88). Through their activities, the students in TP's classroom are learning about various geometric objects by coming to know them. Students, for instance, are led to perceive that three little cubes can be put together to make a rectangular prism, which then would look like the kleenex box in the classroom.

**TM's classroom.** The learning environment in Ms. Trisha Miller's (TM) chemistry unit in science is also discovery oriented. The visual experience which TM facilitates to her students is more than just seeing the powders. Through simple experiments and classroom discussions, the students learn the properties of mystery powders. Students observe, draw, record, and compare what they were seeing to what they already knew.

Brown (1992) suggests that discovering learning on its own may often lead to children developing misconceptions about scientific concepts, and so she suggests guided discovery learning as a way around it. Guided discovery learning "places a great deal of responsibility in the hands of teachers, who must model, foster, and guide the 'discovery' process into forms of disciplined inquiry that would not be reached without expert
guidance" (p. 169). Brown (1992) suggests that teachers should continually engage themselves in guided learning of their students.

*PH's classroom.* PH's diagrams on the blackboard are very simple visual representations of the concepts he is trying to teach. Students learn to develop ways of visualizing these representations as they are created and recreated through PH's set of instructions (e.g., instructions on lunar eclipse). PH also provides interpretations of these representations through gestures and analogies for the students to see and to understand. For instance, PH's gestures and body movements demonstrate to Jean how the moon can block out the sun. PH's use of analogy is very simplified and sometimes it may be superficial. For instance, the comparison of model of an atom to the model of our solar system. Relations among smaller and larger bodies are preserved in the planetary model but not in the atom model. Although PH facilitates visual thinking in his classroom (e.g., diagramming sentences), his instructions for doing so are usually through a lecture format. Students also get to demonstrate their understanding of subject matter through role-playing.

*MB's classroom.* MB's tries to connect visual arts into the classroom curriculum. She works with the classroom teachers to provide them with appropriate resources which the teachers can then use with their class. Before her students make/create art, MB's role is to educate their eyes. The students, for instance, are guided to perceive deeper into Salvador Dali's surrealist works (such as posters, photographs, and slides) so that they may
be able to later use Dali's techniques into their own pictures. Students learn to externalize their thoughts and think imaginatively as they make their own Dali like pictures. MB also provides a demonstration of Dali like background. The visual process in MB’s classroom is organized around learning to see/look at Dali’s art, externalizing/sharing dreams, and drawing pictures.

These data descriptions demonstrate that what counts as visualization is mediated through interactions among the participants. This shows a weakness of the cognitive modeling research which suggests that representations such as visualizations are stored in a person’s memory to be later manipulated by reasoning procedures (Clancey and Roschelle, 1991). A study of everyday visualization then suggests that visualization research should also consider how participants visualize in activity and not just focus on visualizations in the head.

The data descriptions also reveal that the visualization processes in these classrooms did not very much deal with manipulation and orientation in two and three dimensions. Although, the students in PH’s classroom were often led to imagine phenomena in science periods from different viewpoints (“So, imagine us at this side”). Mental rotation of three dimensional objects similar to those used in visualization tests (e.g., Vandenberg and Kuse, 1978) were not presented to the students. Also, we find from the chess descriptions that the students were often guided by PH to recognize, remember, and reproduce tactics (“You all see this I hope”). The visualization processes used in the chess club may be similar to those needed for embedded figure tasks which require the respondents to visually
extract simple patterns or shapes from complex figures. Although, the students in the chess club looked for spatial relations on the chess board which were dynamic and not static as in the embedded figure tasks. Students in the visual arts class were taught how to draw Dali like backgrounds through a demonstration by MB ("make a horizon way back here with some kind of mountains"). It may then be also needed to introduce visualization skills such as those involving manipulation and orientation through various instructional contexts in classroom everyday. This should be done through integration of such visualization skill activities into the science and mathematics curriculum as has already been suggested by Baker and Belland (1986).

INSTRUCTIONAL IMPLICATIONS

This study provides several implications:

1. *Students can often rely on visual and kinesthetic modes of reasoning.* Classroom activity should organize student knowledge and understanding incorporating and encouraging visual and kinesthetic modes of reasoning. This implication is in harmony with other researchers (e.g., Leushina, 1991; Battista and Clements, 1991). Classroom curriculum must create "opportunities for practice" (Lave, 1990, p. 324) so as to generate everyday visualization in various instructional contexts.

2. *Active student participation may yield unexpected opportunities for visualization.* Discussions and hands-on activities focusing on their everyday experiences and observations, and "guided discovery learning," as noted in Brown (1992, p. 169), will enable learners to be active in
structuring knowledge and constructing meaning. Teachers should try "to connect, to enter into each student's perspective" (Belenky, Clinchy, Goldberger, and Tarule, 1986, p. 227 [original emphasis]).

3. Visual arts and concomitant visual thinking can be integrated into the classroom curriculum to enhance the subject objectives (such as in mathematics and science). Teachers can facilitate the visualization of abstract concepts such as points and lines in their classrooms through the visual arts. This has been also suggested by Millman and Speranza (1991). Imaginative thinking and perceptual learning can then be stressed through the visual arts.

4. Visualization can be stressed in all subjects—"[v]isual thinking is indivisible" (Arnheim, 1986, p. 151). Visual representations, illustrations, drawings, or images must highlight important features so as to provide the students with a holistic view of an entire process (such as drawings and redrawings of a total lunar eclipse). Visual representations when externalized through classroom instruction can help organize ways of visualizing for the students. Classroom activities should involve manipulation and orientation of two and three dimensional representations as has already been argued, for example, by Baker and Belland (1986) and Yakimanskaya (1991). Teachers should then encourage students to create and work with visual-spatial images within the context of classroom activity.

5. Instructions to visualize may evolve out of everyday classroom practice. Streibel (1989, p. 16) argues that "everyday instructional design" is always situated in practice. By this he means that there is a gap between instructional design theories and instructional design practice. According to
Streibel (1989), this gap will never be resolved due to the situated nature of the instructional practice. So when the students work with manipulatives or objects, for example, the instructions to visualize must then depend on the specific nature of that activity.

**Recommendations for further research**

This study suggests further research on visualization in classrooms. Keller and Grontkowski (1983) argue, in one philosophical and historical essay on the mind's eye, that the "logic of the visual is a male logic" (p. 207). They point out that although women usually find the sense of touch useful, it is given the status of "lower" sense (as opposed to the sense of sight which has a status of "higher" sense). We find from the data descriptions how girls in one fourth grade classroom found touching/feeling useful for sense-making of the geometric objects ("I think it's more better if you feel it because if you feel it you can get more of an idea—you can feel everything. Just seeing it, you can't feel the texture"). Furthermore, there is no one correct way of seeing and that learning and personal experiences are part of an individual's perceptual process (Harris, 1989). Baker and Belland (1988) have linked the issue of equity to the differences in visual-spatial learning among boys and girls. How can then we provide (or facilitate) ways of visualizing among boys and girls expecting and knowing the differences in their perceptions and preferences? The data descriptions demonstrate how teachers organized instruction to facilitate visualization processes in their classrooms. However, this study did not explore the issue of the
visualization process in classrooms through a gender perspective. Perhaps, future studies should explore this issue.

In this everyday visualization study, we found that the students and teachers created and gave meaning to their visualizations in activity not cut off from it. Students, such as Jacob, formed visual images to aid in their conceptualization of classroom materials. John Dewey once said that "the image is the great instrument in instruction. What a student gets out of any subject presented to him is simply the images which he himself forms with regard to it" (cited in Wileman, 1993, p. 7). The computer as a tool can help facilitate the visualization process in the classrooms (e.g., Belland and Trethewey, 1989). Instructional designers must make provision for students to create their own visual representations or images through the interactions with the computer (Clancey and Roschelle, 1991; Streibel, 1985). The computer interface could provide the students with representational elements (e.g., generic shapes and forms) through which the students can create, manipulate, understand, share, and express their ideas in a visual form. Research in scientific computing (see Siggraph, 1990) is already underway to assist the scientists and students to visualize the scientific and mathematical process under their study. Can such visualization applications also facilitate insight and understanding in the school classrooms? What role would then be for the instructional designers and teachers? This would at least make the everyday visualization process in the classroom an interactive one.
IMPACT STATEMENT

I — Interdisciplinary
M — Model
P — Program in the
A — Arts for
C — Children and
T — Teachers

Arts IMPACT is a teaching/learning approach in which the Arts are infused deeply into the basic academic curriculum. The major goal is to make the educational process more positively productive, more humanizing, challenging and enjoyable for everyone involved — students, teachers and parents. Some basic objectives are:

1. To reinforce the academic instructional program by including the integration of arts activities and skill instruction in the arts for all children.

2. To expand children's creative, appreciative and expressive qualities while cultivating an attitude or "joy in learning" and a "wanting to come to school" outlook that will carry over into the total school program.

3. To allow children the joy of experiencing success and to strive constantly to improve.

4. To help children to become self-directed, self-controlled, self-respecting, dignified human beings.

Teaching and learning the Arts IMPACT way requires much commitment, creativity and compatibility on the part of the teachers, the students and the parents. Participating and integrating the Arts into the curriculum makes Arts IMPACT a dynamic teaching process that requires constant "stretching" of staff and students.
STUDY CONSENT

BEHAVIORAL AND SOCIAL SCIENCES
HUMAN SUBJECTS REVIEW COMMITTEE (HSRC)
THE OHIO STATE UNIVERSITY

Date September 18, 1992

RESEARCH PROTOCOL:
92B0183 EVERY DAY VISUALIZATION: AN INQUIRY INTO FOURTH AND FIFTH GRADE CLASSROOM PRACTICES, John C. Belland, Umesh Thakkar, Educational Policy and Leadership

presented for review by the Behavioral and Social Sciences Review Committee to ensure proper protection of the rights and welfare of the individuals involved with consideration of the methods used to obtain informed consent and the justification of risks in terms of potential benefits to be gained, The Committee action was:

X APPROVED  DEFERRED*
____ APPROVED WITH CONDITIONS*  ____ DISAPPROVED
____ NO REVIEW NECESSARY

*CONDITIONS/COMMENTS:
Subjects were deemed NOT AT RISK and the protocol was unanimously APPROVED WITH THE FOLLOWING CONDITIONS:

1. Provide a letter of support from the school.
2. Add a signature line and obtain the signature of Dr. Belland as the principal investigator on the consent form, and forward a copy to the Committee.
3. Revise the letter to parents to inform them that participation or non-participation will have no effect on their treatment in the classroom.

If you agree to the above conditions, PLEASE SIGN THIS FORM IN THE SPACE PROVIDED BELOW AND RETURN WITH ANY ADDITIONAL INFORMATION REQUESTED TO THE HUMAN SUBJECTS REVIEW DESK, 300 RESEARCH FOUNDATION, 1960 KENNY ROAD, CAMPUS, within one week. Upon such compliance, the approval form will be mailed to you. (In case of a deferred protocol, please submit the requested information at your earliest convenience. The next meeting of the Committee will be two weeks from the meeting date indicated above.)

DATE __10/5/92__ Signatures(s)
Principal Investigators

HS-025A (Rev. 2/91)
(CONDITIONS/COMMENTS)
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