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The Graduate School

ELEMENTARY CHILDREN'S EPISTEMOLOGICAL BELIEFS AND UNDERSTANDINGS OF SCIENCE IN THE CONTEXT OF COMPUTER-MEDIATED VIDEO CONFERENCING WITH SCIENTISTS

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

Janie Mefford Shaklee

College of Education
Educational Psychology
August, 1998

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THIS DISSERTATION WAS SPONSORED

BY

Teresa M. McDevitt, Ph.D.

Janie Mefford Shaklee

DISSERTATION COMMITTEE

Advisory Professor

Jeanne E. Ormrod, Ph.D.

Advisory Professor Brenda Sugrue

Brenda M. Sugrue, Ph.D.

Advisory Professor Robert E. Nahory

Robert E. Nahory, Ph.D.

Faculty Representative Francis A. Griffith

Francis A. Griffith, Ph.D.

DEAN OF THE GRADUATE SCHOOL

Richard A. King

Examination Date of Dissertation May 4, 1998

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ABSTRACT

Shaklee, Janie Mefford. Elementary Children's Epistemological Beliefs and Understandings of Science in the Context of Computer-mediated Video Teleconferencing with Scientists. Published Doctor of Philosophy dissertation, University of Northern Colorado, 1998.

The relationship between children's epistemological beliefs and their understandings of the processes of science was explored in this study. In addition, changes in children's understanding of science when exposed to remote scientists doing science was investigated.

The context for the study was a self-contained, multi-level elementary Colorado classroom (combined second, third and fourth grades, n=22). Two Colorado classroom teachers collaborated with scientists in New Jersey, via computer-mediated video teleconferencing over ISDN lines, providing Science instruction for this distance education experience.

Data on the children's understanding of science were gathered using a drawing/interview process. Coding was developed according to categories based on the National Science Education Standards (1996). Students were found to have increased their understanding of science based in this brief contact with scientists. Results of the epistemological investigation were inconclusive. Further study, with a larger sample size, was recommended.

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CHAPTER I

INTRODUCTION

In this dissertation, I examined the epistemological beliefs and understandings of children exposed to scientists through technology-based communication. Specifically, I investigated children's understandings of science processes, and correlates of and changes in these understandings. The investigation was grounded in several literatures.

The context for the study was a multi-level elementary classroom receiving science instruction via distance education. Remote scientists collaborated with the classroom teachers in providing science instruction geared to meet the National Science Education Standards (1996). The students were studied using various measurements in an attempt to create a rich portrait of the developing epistemologies and science process understandings of young children prior to and after participation in distance education with scientists.

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Data were collected via questionnaires, drawings, and interviews. The data were analyzed with correlation coefficients, factor analysis, linear regression, and t-tests.

The Need for the Study

In this section the need for this exploratory study is discussed. First, the social press for improvement in American science education for children is described (IEEE, 1997; TIMSS, 1996). Next, national and state efforts to raise science education levels by providing and legislating science achievement standards are reported (CO HB95-1313; NSES, 1996). Third, Public Electronic Access to Resources for Learning (Project PEARL; Nahory, Harbison, Wullert, & Gilchrist, 1995), an instructional program using technology to facilitate collaboration between scientists, teachers and students, is described (NSES, 1996; Linn, Songer, & Eylon, 1996). Last, children's epistemologies are presented as individual differences that may mediate individual students' science performance (Hofer & Pintrich, 1997).

Present Limitations in Science Education.

There is a growing gap between the increasingly technical job market and the scientific capability of America's workforce (IEEE, 1997). Business leaders express a need for increasing students' participation in science education to remedy this gap. Unfortunately, education researchers report that by the end of tenth grade half of all

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American students have abandoned science (Smith, Young, Bae, Choy & Alsalam, 1997). This dismal condition indicates that attempts to improve science education in high school or college arrive too late for many students, who may already have self-selected themselves out of advanced science classes. Research indicates that individual American students' performance in science tends to decline after the sixth grade (TIMSS, 1996). Further, compared to college-bound students in other countries, American students score in the lowest quartile in chemistry, biology and physics (TIMSS, 1996).

In response to this poor performance, numerous professional, political and educational organizations have proclaimed the need for scientific literacy for all students (NSES, 1996). The National Science Education Standards (1996) were developed to help meet this goal. They serve as model curriculum guidelines that educators can adapt for local implementation.

Yet, meeting these standards is only possible if students participate in the science curriculum. When high school students gain control over their schedules, most opt out of advanced science courses so that even improved science instruction targeted at achieving standards misses the majority of students (Smith, Young, Bae, Choy, & Alsalam, 1997). The greatest opportunity to provide quality science instruction to all students may occur prior to the high school level. Enhancing science education for elementary age

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students may lead to long term commitment to science by a larger number of students.

What is not known is how best to encourage students to pursue further science education. Many reforms at the systemic level have been implemented. Some examples include improving curriculum, requiring more science credits for high school graduation, enhancing science teacher preparation, and modifying textbook content (Cobel & Koballa, 1996; NSES, 1996; TIMSS, 1997). These reforms have resulted in increased science achievement by more students, but the majority of American students still do not benefit from current science educational efforts (Cobel & Koballa, 1996).

Technological Support and Partnerships in Science Education.

What more can be done at a systemic level? Comprehensive strategies that are motivating to students, efficiency in use of resources, and accurate information seem to be needed. Technologies, such as computers and the Internet and video teleconferencing could be employed to extend classroom resources (NSES, 1996). Video teleconferencing is an attractive interactive technology, which lends itself well to encouraging student participation in science. Perhaps a collaborative approach to science education (facilitated by technology) among scientists, teachers, researchers and students could help as well (Linn et al., 1996).

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It may be that early exposure to the processes of science as practiced by remote working scientists collaborating with classroom teachers could lead to the development of a richer, more integrated view of science for the affected students. Such exposure may assist students in developing a better understanding of science. Students with a better fundamental understanding of science, in turn, might be more likely to attempt higher level science classes in the future.

Acknowledgment of Students' Beliefs in Science Education.

Can we enhance children's understanding of science processes without examining their prior beliefs? Educators have shown commitment to assessing prior beliefs in content areas (Schoenfeld, 1983). Perhaps they also need to recognize that students hold influential beliefs about origins and justification of science inquiry.

Personal natural epistemologies, or beliefs about the nature of knowledge (as distinct from Piaget's genetic epistemology), appear to influence the academic achievement of older students (Hofer and Pintrich, 1997; Linn, et al., 1996; Schoenfeld, 1983; Schommer, 1993). Studies with high school and college age students indicate that epistemological beliefs influence how these students approach academic tasks (Hofer & Pintrich, 1997). For example, Schommer (1993) found a relationship between adult students' beliefs and their

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comprehension of mathematical texts. She also found that there is a relationship between adolescents' epistemology and their academic performance (Schommer, Calvert, Gariglietti, & Bajaj, 1997).

There is an established body of work dealing with the epistemologies of older students, but little is known about the development of natural epistemological beliefs of children between age six and adolescence (Hofer & Pintrich, 1997). This may be partly due to the influential views of developmental theorists, who attribute a limited general epistemology to children constrained by their concrete-operational thinking (Chandler, 1988; Piaget, 1929). An objectivistic or absolutist epistemological perspective holds that there is one truth, one objective reality (Wellman, 1990), and theorists agree that elementary school students hold objectivistic epistemologies, although they have not published studies that include elementary age children. It seems unlikely that epistemological beliefs suddenly appear in adolescence, without precedent (Chandler, 1987).

Could it be that natural epistemological orientations influence the choices individual students make regarding science education? Do natural epistemologies influence learning at an elementary school age? If so, how is science understanding mediated by students' natural epistemologies? In this study I begin to attempt to answer these questions.

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Background of the Problem

In this section I will first discuss five dimensions of epistemology and eight elements of the processes of science. Next, I will suggest conceptual relationships between them.

Epistemology.

Natural epistemology is defined in this study as an individual's collection of beliefs about the nature of knowledge and the acquisition of knowledge. Natural epistemology is an important consideration for educators when designing and implementing science curricula. Children's basic beliefs about how learning takes place and how knowledge is structured and validated influence what they choose to learn about how science is conducted.

The theoretical foundation for this view of natural epistemology is found in the work of Schommer (1989, 1994b, 1994c, 1995). In Schommer's view, learning may be affected by single beliefs and combinations of beliefs. In addition, epistemological beliefs do not necessarily develop in synchrony. Her current work describes epistemological beliefs as a system of more or less independent dimensions.

Both college students' and adolescents' epistemological beliefs have been researched using Schommer's (1989) five dimensions. These dimensions are described as general beliefs about:

1) the source of knowledge (knowledge is handed down by authority vs. derived from reasoning and logic)

2) the <u>certainty</u> of knowledge (knowledge is absolute vs. tentative and evolving)

3) the <u>structure</u> of knowledge (knowledge is isolated bits vs. interrelated facts)

4) the <u>control</u> of learning acquisition (ability to learn is innate vs. acquired)

5) the <u>speed</u> of learning acquisition (learning is a quick vs. a gradual process)

These dimensions critically affect what high school and college students learn and how they learn it (Schommer, Crouse & Rhodes, 1992; Schommer, 1994a). For example, high school students' grade point average may be predicted by the extent of their belief in quick learning (Schommer, 1993). Beliefs in quick, all-or-none learning affected both the degree to which college students integrated knowledge and how precisely they monitored their comprehension. Further, college students' interpretation of complex text was affected by their epistemological beliefs. When presented with tentative information, students with strong beliefs in the certainty (absoluteness) of knowledge distorted the information to conform to their beliefs.

If, as Schommer's research indicates, personal epistemology affects what adults and adolescents learn, then it is likely that children's mastery of scientific processes may be influenced on the basis of their developing beliefs. For example, the dimension "certainty of knowledge" is viewed as extending from <u>knowledge is absolute to knowledge is</u>

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constantly evolving. Schommer (1990) supports this concept with her own research on reading comprehension. She found that students who had strong beliefs in certain knowledge interpreted tentative knowledge as absolute. Asking probing questions about the unknown is unnecessary if knowledge is absolute, thus asking science questions would be difficult for an absolutist.

Processes of Science.

Science process skills are being targeted for improvement. This is evidenced by national efforts, such as the National Science Education Standards, legislated state science standards, such as those of Colorado, international comparative studies such as the Third International Mathematics and Science Study and the history of American science education reforms (NSES, 1996; TIMSS, 1996). The decentralized nature of American education and the 'incremental assembly line' philosophy in American society makes this improvement a complex task (Anagnostopoulos & Williams, 1998; IEEE, 1997; Schmidt, 1997). Although defined differently by various organizations, science process skills have been a frequent target for enhancements. Educators and scientists alike have argued that understanding how scientific inquiry takes place -- through hypothesizing, controlling variables, making observations, and relating data to theory, for example -- is an essential component for the improvement of scientific literacy. In the present study,

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the National Science Education Standards (1996) are appropriated as a model of the processes of science.

In the National Science Education Standards (1996) "processes of science" (p. 105) is a term used to describe a complex vision of scientific inquiry, including the understanding of the nature of science and the skills needed for inquiry. This "processes of science" view suggests that students come to their understanding of science by combining critical thinking processes with scientific reasoning.

The NSES K-4 standard on "science as inquiry" lists six concepts and abilities that are necessary in order to engage in scientific inquiry (NSES, p. 141). The "nature of science" standard sets forth two additional concepts needed to understand the nature of science (NSES, p. 123). In this study these eight items will be referred to as 'elements' of the processes of science:

1) Ask a question
2) Plan a simple investigation
3) Employ simple equipment
4) Use data to construct a reasonable explanation
5) Apply technology
6) Communicate investigations and explanations
7) View science as a human task
8) Check each other's work

These eight elements of the processes of science have been used for operationalizing the measurement of student understandings in this study.

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Synthesis of the Investigation.

In the present study I have examined relationships among Schommer's five specific dimensions of epistemology and children's understanding of the "processes of science." Research on children's theory of mind suggests that an active-interpretive quality of mind pre-dates the constructivistic epistemology that develops sometime after age six (Wellman, 1990). Natural epistemologies pre-date children's exposure to formal classroom science instruction, thus children arrive at school with varying naive beliefs about the world that surrounds them. Usually it is the task of the teacher to introduce them to the social process of acquisition and validation of knowledge, which we call science.

A pilot study was conducted to test the instruments and administration processes. Modifications were made where necessary. First, measurements of children's epistemology were taken. Items on the simplified epistemology questionnaire were based on Schommer's (1996) most recent work. Next, children's understandings of the processes of science understanding were measured. Classroom teachers and remote scientists provided three weeks of science instruction. Epistemology and processes of science measurements were repeated following the instruction. A supplementary measure of processes of science was executed, for instrument reliability purposes. The data were

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analyzed to determine if Schommer's epistemology factors could be replicated in a younger population, to investigate if epistemological beliefs influenced children's understanding of science, and to determine whether exposure to video teleconferencing with scientists influenced children's understanding of how science is conducted.

Treatment Context

Students in most elementary schools receive their science instruction from their classroom teacher (TIMSS, 1996). Although reforms have led to a focus on hands-on and minds-on experience during science instruction, in reality, many students have little exposure to the every day work life and reasoning of scientists (TIMSS, 1996). With such exposure, their beliefs about the processes of science might change. Computer mediated video teleconferencing makes exposure to scientists possible, bringing remote resources into the classroom in a distance learning experience. Both the technology and the instructional design developed by the teachers and scientists constituted the learning context for this study.

In the University of Northern Colorado (UNC) Laboratory School, computer-mediated video teleconferencing was used by the classroom teachers to bring Project PEARL (Public Electronic Access to Resources for Learning) to their students. Project PEARL provided electronic field trips to students in various states. Sponsored by Bellcore and located in New Jersey, Project PEARL supported educational

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opportunities through broad band communications (Nahory, Harbison, Wullert, & Gilchrist, 1995). At the UNC Laboratory School, teachers worked as partners with scientists in creating a curriculum which fit with the science standards mandated in Colorado by the 1995 House Bill 1313. These standards are similar to those published as the NSES (1996).

As part of project PEARL, working scientists collaborated with classroom teachers in providing science instruction to second, third, and fourth graders. This application of a cognitive apprenticeship approach (observation, coaching, and successive approximation) to science instruction may increase the understanding of processes of science in younger children (Collins, Brown & Newman, 1989).

The NSES (1996) suggested that schools employ new communications technologies to amplify the use of classroom science resources to improve science instruction (p. 221). This study responded to this NSES suggestion in a naturalistic field experiment with pre- and post-measures of the epistemology of children and their understanding of the processes of science in a pre-existing elementary classroom.

Purposes of the Study

The purpose of this study was to investigate the relationship between epistemology of young children and their understanding of the processes of science. These factors were viewed in the unusual context of a classroom of elementary students receiving instruction via computer

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mediated video teleconferencing with scientists. Children completed pre- and post-measures of epistemology and the processes of science.

A questionnaire using Schommer's five dimensions of epistemology was used to measure children's epistemology. The epistemology questionnaires was factor analyzed. The understanding of the processes of science was evaluated with drawings and process interviews, which were further coded and scored. A t-test was used for science pre- and post-test analysis.

Research Questions

The research questions for this study were derived from the definitions of epistemology and the processes of science as well as from current research and thinking in the field. These questions were:

1. What is the relationship between children's epistemological beliefs and their understandings of the processes of science?
2. How does understanding of the processes of science change when children are exposed to scientists doing science?

Definition of Terms

Integrated Services Digital Network (ISDN). The video conferencing took place over ISDN lines, a public-switched digital network operating at 128 kb/sec. ISDN lines were installed by the local telephone company and were accessed using two phone numbers, one for each line.

Computer Mediated Video Teleconferencing. Computer-mediated video teleconferencing is a Personal Computer-Based two-way video technology operating over ISDN lines. In this study the classroom was equipped with the following equipment:

1. Intel Pro Share video conferencing boards
2. Pentium computer, camera and software with screen sharing capability
3. VGA to NTSC converter, which allows the computer screen to be displayed on a large TV monitor

Personal Epistemology. A personal epistemology is an individual's multi-dimensional system of beliefs about the nature of knowledge and how it is acquired. Five dimensions are considered in this study: (a) source of knowledge, (b) certainty of knowledge, (c) structure of knowledge, (d) control of learning, and (e) speed of learning.

Processes of Science. The National Science Education Standards (1996) provide a complex vision of scientific inquiry, including the understanding of the nature of science and the skills necessary for inquiry (NSES, 1996). Eight elements of the process of science have been included in this study: (a) ask a question, (b) plan a simple investigation, (c) employ simple equipment, (d) use data to construct a reasonable explanation, (e) apply technology, (f) communicate investigations and explanations, (g) view science as a human task, and (h) check each other's work.

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Limitations of This Study

Restricting this study to one classroom in a university laboratory school is a context limitation, as the setting is unusual and results may not generalize. The lack of a control group in this experimental design raises internal validity issues. History may be a problem as the children had other educational experiences in their classroom during the period of intervention. Subject maturation may also pose difficulties as the children were growing and developing during the span of the intervention. The children were twice exposed to the same test, increasing the possibility that boredom may be a factor, and test reactivity could be a threat. Other testing influences may also have been present because the subjects' awareness of the topic under investigation may have increased with test exposure. Memory could have been an influential factor, as students might have remembered how they responded the first time and responded in the same way again. The treatment was brief, and therefore unlikely to impact epistemological beliefs. No follow-up data were collected.

Practical issues (for example, ISDN wiring, computer equipment) made restricting the scope of the study unavoidable, resulting in a small sample size. Thus, the results are not generalizable to national, state or local populations.

The epistemology questionnaire, validated with adults and adolescents, has not yet been used for a population of

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this age. Age-appropriate adaptations were made in consultation with the author of the scale (Schommer, 1989, 1996), but the meaning of items for children is not certain. Validity for an elementary population remains unresolved, however, this study attempts to establish it.

The science drawing test was a new measure, developed for this study. Content validity was derived from the categories in the NSES.

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CHAPTER II

REVIEW OF THE LITERATURE

In this chapter theoretical and empirical studies are reviewed. Literature tracing the changing social perspectives on science education and psychological views of the learner over the past half-century are reviewed, by decade. Major science trends from logical positivism through a 'new' philosophy of science into constructivism are traced. The National Science Education Standards (NSES, 1996) takes threads from logical positivism and the 'new' philosophy of science and weaves them together into a contemporary view of desirable scientific inquiry. Implied by the NSES is a constructivistic perspective on learning. This standards perspective is supplemented with a concern for learners' beliefs about knowledge acquisition. Schommer's (1989) theory of epistemology suggests that children's beliefs are likely to influence their learning in various ways, and her work is reviewed here as the theoretical basis for this study on children's epistemology and science learning.

Issues in Science Education

The purpose of this section is to provide an historical, conceptual and philosophical context for the

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usage of the National Science Education Standards (1996) in this investigation. Historically there have been epistemological developments in the field of science education that have influenced what is taught as science, how science is taught and who learns science. As educators, we have gradually become aware that we might influence our students' epistemological beliefs with our implicit models of where knowledge comes from and how it is justified.

Three literature reviews by Cleminson (1990), Meichtry (1993), and Linn, Songer and Eylon (1996) sketch a progressive portrait of some historical models influencing contemporary American science education, research into science education and current views of learning and instruction. Taken together, these papers provide insight into the paradigms dominant in science education at the time of the publication of the National Science Education Standards (NSES) in 1996.

Cleminson (1990) proposes an epistemological basis for science teaching, Meichtry's review (1993) discusses students' understanding of the nature of science and the influence of science curricula, and the most comprehensive paper, by Linn et al.,(1996), reports on science learning and instruction.

A Conceptual History of Science Education in America.

During the past fifty years American science education has gradually shifted away from educating future scientists,

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who are expected to produce technology, toward achieving scientific literacy for all students (Meichtry, 1993, NSES, 1996). This shift is discussed, by decade, in the remainder of this section.

1950s.

Until the 1950s science educators generally assumed a knowledge absorption model of the learner (Linn et al., 1996). Science content was transmitted to students who were presumed to have started with no prior knowledge (Cleminson, 1990).

1960s.

In the 1960s and the 1970s the idea of a passive learner was still common, but a substantial developmental model emerged (Linn, et al., 1996). Students were expected to learn science within the constraints of their current developmental level. Perhaps due to "a fusion between inductivist ideas about scientific method with child-centered views of education" (Cleminson, 1990, p. 430), discovery learning methods were adopted. It was anticipated that students would learn as they exercised their processing capacity and developed scientific inquiry abilities (Linn, et al., 1996). The processes of science began to be addressed during instruction. Students were taught the process of observing objectively. Unbiased observation was simply expected to result in student concept formation. Unfortunately for the learners, the difficulty of concept formation was underestimated (Linn, et al., 1996).

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Meanwhile, interest in measuring understandings of the nature of science was growing. Various instruments were developed. For example, Kimball (1968) developed a fundamental nature of science theoretical model. This model was used as the basis for an instrument dedicated to measuring teachers' understanding of the nature of science. This instrument, the Nature of Science Scale (NOSS), was also used for high school students.

The following eight statements defined this model:

1. Curiosity is the fundamental driving force in science.
2. Science is a dynamic, on going activity.
3. Science aims at comprehensiveness and simplification.
4. There are many methods of science.
5. The methods of science are characterized by attributes that are more in the realm of values than techniques.
6. A basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding.
7. Science has a unique attribute of openness.
8. Tentativeness and uncertainty mark all of science. (p. 430)

Items two and eight reflected an epistemological orientation similar to Schommer's (1989) epistemological dimensions. Schommer's (1989) 'certainty of knowledge'

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dimension reflects a continuum of beliefs about knowledge, from knowledge is absolute to knowledge is constantly evolving. It may be necessary for a student's epistemological beliefs to be nearer to the knowledge is constantly evolving point in order for him or her to perceive science as a dynamic and uncertain domain.

1970s.

In the 1970s, the developmental model of student learning increased in popularity. This led to the institution of reforms, intended to increase student participation in science courses. Teachers taught less quantity of science while implementing curricula that related the history of scientific ideas and emphasized hands-on experiences with scientific phenomena (Linn et al., 1996). This approach was not successful in attracting more students into science courses (Linn et al, 1996).

Two conceptual perspectives, which emerged during this period, are of particular importance to this investigation. These perspectives are Lakatos' (1970) views on the history of science, and Mumby's (1976) classification of attitudes toward science.

Lakatos (1970) described the composition of the history of science as competing research programs conducted by scientists. These competing research programs included "negative heuristics" (rules on what research directions should be avoided) and "positive heuristics" (rules about what research direction may be pursued). Cleminson (1990)

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proposed that Lakatos' work was important to understanding trends in the 1970s because Lakatos (1970) viewed science as a creative human endeavor. This view was integrated into the NSES in 1996 and will be used in this investigation as an element of science understanding.

Mumby (1976) analyzed scientific texts and categorized them into one of two philosophical contexts: realism and instrumentalism. These two contexts reflected different ideas about the processes of science. In Mumby's (1976) words: "while Realists hold that scientific theories and explanations are true and absolute descriptions of the world, Instrumentalists regard scientific theories and explanations as instruments for ordering perception--they are not true or false but are more or less useful" (p. 116). Mumby (1976) suggested that students would arrive at quite different understandings based on the orientation of their instructional experience. A similar position is taken in this investigation, that elementary student understanding about science is likely to be different in orientation due to early instructional exposure to scientists.

1980s.

During the 1980s there was a movement towards reform of science education largely influenced by two factors (Linn et al., 1996):

1. recognition that science education needed to be extended to all students.

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2. evidence that science courses were not succeeding. Students simply lacked science understanding.

This concern that science education be both more inclusive and effective for individual learners was occurring as curricular perspectives were shifting.

Cleminson (1990) reported that two instructional perspectives emerged during the 1980s:

1. that contemporary views on the philosophy of science should be reflected by science curricula.

2. that instructional practices should be based on the current understanding of concept learning.

Cleminson (1990) suggested that there were two major views in the philosophy of science in the 1980's. The dominant paradigm was logical positivism and a 'new' philosophy of science that began to emerge.

The definition Cleminson (1990) provided for logical positivism was based on Ambiola's (1983) philosophical view. His moderate position combined common beliefs of several different philosophical perspectives. Ambiola (1983) argued that moderate logical positivists would agree that they valued scientific theory and explanation, the hypothetical-deductive method, the use of symbolic logic, observation as a neutral activity and commitment to empirical sciences. In addition, Ambiola (1983) perceived consensus in the view that increases in scientific knowledge occured via accretion and via applying objective criteria in validation of scientific discoveries.

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Cleminson (1990) described a 'new' philosophy of science in the following manner:

> Knowledge, beliefs and theories determine our perception. Man (sic) is in no sense a tabula rasa for the reception of sense impressions; rather he has developed lenses through which he perceives the world and that determine to a large extent, what counts as an observation. These lenses include the paradigms (Kuhn, 1970), presuppositions or research programs (Latakos, 1970) within which the scientist operates. (p. 433)

Personal epistemological concerns in teaching science and learning fit well within this model. This view of science acknowledged the importance of beliefs that influence perception and thus learning. In the present study, the epistemological beliefs of children are viewed as the lenses through which they perceive science. How do they influence children's understanding of science?

Contrasting logical positivism with the 'new' philosophy of science, Cleminson (1990) articulated the following assumptions:

1. Scientific knowledge is tentative and should never be equated with the truth. It has only temporary status.
2. Observation alone cannot give rise to scientific knowledge in a simple inductivist manner. We view the world through theoretical lenses built up from

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prior knowledge. There can be no sharp definitions between observation and inference.

3. New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry. As such, science is a personal and immensely human activity.
4. Acquisition of new scientific knowledge is problematic and never easy. Abandoning knowledge that has been falsified usually occurs with reluctance.
5. Scientists study a world of which they are a part, not a world from which they are apart (Cleminson, 1990, p. 438).

In this tradition, Cleminson (1990) suggested that the essence of science be viewed as a process of continuous cycles of research and criticism. The NSES (1996) also ascribed to this view, and it is included as one of the elements of the processes of science in this study. This element (check each other's work) is based on the NSES (1996) assertion that scientists review the work of other scientists and question the results and the processes of investigation.

1990s.

In the 1990s educational psychologists developed a metacognitive model for teaching science (Linn et al, 1996). The hope was that science might be taught more successfully by using cognitive information on how students organize and integrate knowledge (Linn et al, 1996). "In the abstract, a

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metacognitive model means that a student will engage in self-monitoring, reflection, planning and knowledge integration" (Linn et al, 1996, p. 480).

Including metacognitive concerns led to a new focus on communicating the nature of science knowledge rather than simply providing science information (Linn et. al., 1996). A problem encountered in encouraging metacognition is that textbooks tend to present science concepts as universal truths, which hinders metacognitive use (Linn et. al., 1996). In epistemological terms this textbook approach would be a dualistic (or absolutist) presentation of scientific knowledge, thus discouraging the process of questioning.

Scientific Literacy and the Nature of Science

Scientific literacy, as portrayed in the literature reviewed in this section, includes understanding the nature of science and the nature of scientific knowledge. Scientific literacy is presented by these papers as the primary objective of contemporary public science education (Cleminson, 1990; Meichtry, 1993; NSES, 1996; Linn et al., 1996). Some of the literature identifies attributes of the scientifically literate person. Cotham and Smith (1981) suggest that the public's support of scientific enterprise is influenced by their scientific literacy. For example, Duschel (1990) noted that revisions of scientific ideas are acceptable to scientifically literate persons, as they grasp the developmental nature of science. An understanding that

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science is tentative and revisionary is crucial to prevent cynicism about rapidly developing fields (Cotham & Smith, 1981). In a supplementary perspective, Mullins and Jenkins (1988) argue that individual scientific literacy provide the intellectual skills needed to make decisions in a technological and scientific world.

Despite the social importance of scientific literacy, Arons (1983) suggests that the rapid pace and excessive volume of material caused past attempts at general scientific literacy to fail. Arons (1983) observes that frequently science instruction is presented out of context. Yet there exists much research (on intuitions, misconceptions and alternative frameworks, Pfundt & Duit, 1991) that seems to maintain that students' ideas about science are context specific. In hopes of providing information that might facilitate the achievement of this educational goal, science education researchers currently engage in collaborative research focused on students' opportunity to learn (instruction) and on their individual dispositions to learn (Linn, et al., 1996).

Achieving national scientific literacy is complicated by the lack of agreement on the elements that constitute such literacy. A specific problem encountered in preparing for this study was the elasticity of terms such as "nature of science". Along this line, Cleminson (1990) pointed out that "no standard definition for either the nature of science or scientific knowledge exists" (p. 432). However, a case can

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be made that there are similarities in beliefs about the characteristics of nature of science and scientific knowledge. Meichtry (1991) notes that there is no standardized definition of what constitutes students' adequate understanding of the nature of science. This lack of consensus on what constitutes the nature of science has not stopped researchers from attempting to quantify student understanding and misconceptions about the nature of science. Instead, researchers individually define the nature of science knowledge and the nature of science for their specific study. For example, Cleminson (1990) states that the nature of science "includes not only the nature of scientific knowledge but the nature of the scientific enterprise and the nature of scientists as well" (Cleminson, 1990, p. 430). In 1989 the American Association for the Advancement of Science presented yet another definition, including three principal components of the nature of science, as defined by the National Council on Science and Technology Education (NCSTE):

1. Scientific world view--the world is understandable, scientific ideas are subject to change, scientific knowledge is durable, and science cannot provide complete answers to all questions;
2. Scientific methods of inquiry-- science demands evidence, science is a blend of logic and imagination, science explains and predicts,

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scientists try to identify and avoid bias, and science is not authoritarian; and

3. Nature of the scientific enterprise-- science is a complex social activity, science is organized into content disciplines and is conducted in various institutions, there are generally accepted ethical principles in the conduct of science and scientists participate in public affairs both as specialists and as citizens. (NCSTE, p. 29)

Despite the lack of definitional consensus, Meichtry (1991) concludes that understanding the nature of science and the nature of scientific knowledge is important because it is necessary for scientific literacy.

The controversy on the definition of the nature of science remains, but there are areas of consensus, in particular on the need for national scientific literacy. To tap into these areas of agreement, this study adopted the definition of the nature of science as stated in the National Science Education Standards (1996). The NSES are the product of a major collaborative effort, which included individuals from the following groups: "teachers; science supervisors; curriculum developers; publishers; those who work in museums, zoos, and science centers; science educators; scientists and engineers across the nation; school administrators; school board members; members of business and industry; and legislators and other public officials" (NSES, 1996, p. ix). Thus the NSES position on the important components of science

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education enjoys broad support from science education stakeholders.

Students' Understanding of the Nature of Science.

The above section has highlighted the need for improved science literacy. This literacy hinges on understanding of the nature of science. Unfortunately, it has been shown that students in grade six through college have an inadequate understanding of the nature of science (Welch, 1981). Rubba, Horner, and Smith (1981) report that 30% of high school students believe the misconceptions that scientific research reveals absolute truth and that scientific theories mature into laws. Meichtry (1991) concludes that sixth, seventh and eighth grade "... students did not believe scientific knowledge to be partially a product of human creativity, tentative, capable of empirical test or that the specialized sciences contribute to a network of interrelated laws, theories and concepts" (p. 435).

The National Assessment for Educational Progress (NAEP) tested 9, 13, and 17 year-olds' understanding of the nature of science. The NAEP study concludes that the nature of science understanding improves more between grades 7 to 11 than between grades 3 and 7. "According to NAEP, these findings suggest that curricular attention to fundamental aspects of the nature of science appears comparatively limited in elementary school" (Meichtry, 1991, p. 435).

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Teachers cannot be expected to be experts in all domains, but they can collaborate with experts. Perhaps the inclusion of scientists in the science education of younger children, as in the present study, could improve their understanding of science fundamentals. Scientists may be especially compelling models of how science is conducted. Scientists can demonstrate processes of science as well as comment on the combined fallibility and integrity of the methods.

American Science Education.

Stakeholders in American education are clamoring for better science education. Professional organizations such as the Institute of Electrical and Electronic Engineers (IEEE) contend that the public education system is archaic. George Fisher (1997), Chairman of Eastman Kodak, articulates his concerns below:

> In education, the nine-to-three day, the 180-day year, the 45-minute instructional period, the multiple choice test, and teachers lecturing students are the equivalent of a late 19th century factory. Like the manual typewriter, telegraph, telegram, rotary-dial telephone, and hierarchy management models of the 1950's, they must not survive into the 21st century. If teachers are to be more effective, if instruction is to be enhanced, and if educational performance is to rise to meet the challenge of tomorrow, many of these educational

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> anachronisms, like yesterday's technology, will have to be discarded. It is a daunting challenge. (p. 1)

The IEEE-USA Precollege Education Committee has encouraged its members, individual engineers, to improve education. This committee reports a gap between the availability of a trained workforce and America's job market. Currently, more than half of new jobs require some form of technological literacy. Because the U.S.A.'s K-12 education system is decentralized, the IEEE-USA Precollege Education Committee advises its members to take action at a local level.

International achievement comparisons are also often used in calls for reform. For example, the United States' report on the curriculum analysis component of the Third International Mathematics and Science Study (TIMSS) sponsored by the International Association for the Evaluation of Educational Achievement (IEA) summarizes data from the TIMSS curriculum analysis, and integrates it with teacher questionnaire data from the USA, Japan and Germany on science and mathematics topic coverage and instructional practices (Schmidt, William, Knight, Curtis, Raizen, & Senta, 1997). The TIMSS authors discuss the unfocused nature of U.S. mathematics and science curricular intentions, textbooks and teacher practices. They report that earlier calls for curricular reform resulted in new content added to old instructional materials, rather than in fully restructured materials. Teachers attempt to cover too many topics, in an

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'incremental assembly line' approach. The TIMSS report reveals that 4th grade students' science performance was outstanding, but that by 8th grade performance has deteriorated. It appears that curricula are more focused for fourth graders than for 8th graders. However, children's performance in physical science is poor at both ages.

The National Center for Education Statistics (NCES, 1997) reports that high school students abandon science in large numbers. Biology, generally a required subject, is studied by 93.5% of American students. Chemistry is studied by 56% of students, and Physics by only 24.4% of students. Although these figures represent an improvement over 1982 statistics, they indicate that most students abandon science education before they arrive at the level of Physics.

The present study responds to a need for further study with elementary age children. To what can we attribute children's shallow understanding of science? Is the problem curricular? Children may hold misconceptions of the nature of science because their curriculum simply does not include instruction that addresses these issues. The state of Colorado seems to have identified this as the problem and attempts to remedy it by mandating minimum curricular content "standards" (Colorado HB95-1313, 1995). Nationally, standards for science education have been developed which may be used as curricular models by states desiring to do so (NSES, 1996). The NSES present a comprehensive view of science that includes the nature of science. In this study

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national "standards" have been used to measure science understanding.

The state and national curricular remedies do not address children's individual dispositions to learn science. It is possible that children are resistant to efforts at teaching them science concepts at variance with their individual underlying epistemological beliefs. For example, a young student who believes that learning must occur quickly if is to occur at all might stop attempting to implement a scientific investigation simply on the basis of believing that too much time has elapsed. If this is the case, then curricular remedies and pedagogical interventions are unlikely to succeed unless they take stock of children's epistemological beliefs. The present study attempted to identify these beliefs.

Standards

Concerned citizens in the 1990s grew to believe that children were not learning enough in schools, and were simply being promoted on the basis of 'seat time'. Many students were perceived as being scientifically illiterate (concern also existed for inadequate student performance in other domains, but these are beyond the scope of this study). This public perception led to a movement to establish knowledge 'standards' that students would be expected to meet before they could be promoted to the next grade. In Colorado, 'standards' were legislated in 1993. This left schools scrambling to either develop their own or to find acceptable

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'standards' which had been developed elsewhere. The National Science Education Standards of 1996 were written in this climate of political pressure and scholastic need.

The National Science Education Standards.

In this section the National Science Education Standards (NSES) published by the National Research Council in 1996 are reviewed. The social importance of scientific literacy, varying views of the nature of science and new perspectives on student learning were all important components in the development of the NSES (1996).

The National Science Education Standards (1996) were the result of the collaboration of hundreds of people who in turn offered their manuscripts for review to thousands of peers. This process resulted in a consensus on the elements of science viewed as critical by "teachers, school administrators, parents, curriculum developers, college faculty and administrators, scientists, engineers and government officials" (NSES, 1996, p. 3).

The NSES (1996) were written in response to a national goal calling for the scientific literacy of all American students. The NSES (1996) articulated what students need to know, understand and do in each grade level to achieve scientific literacy.

The NSES (1996) are a resource available to local school systems (such as the UNC Laboratory School in this study) under pressure to devise standards for student achievement.

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In addition, the NSES (1996) are representative of current thinking on science education. They are also a product of the current relationship between politics and education.

The NSES (1996) advocats the view that science learning is an active process, in which students must engage both physically and mentally. A distinction is drawn between the skills required to engage in the processes of science (observation, inference, and experimentation) and inquiry, the central learning process:

> When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. (NSES, 1996, p. 2)

The NSES (1996) ultimately serves as the definitive source for the elements of science used to define the processes of science in this investigation. Content standards for each grade level are described in the NSES, and it is from these content standards that the elements of science used in this study to indicate science understanding are derived. For example, the NSES states that educational technology consists of "tools used by students and teachers to conduct inquiry and understand

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science" (NSES, 1996, p. 24). This statement is interpreted in this study as an element of science titled 'Technology.'

Distance Education

This study was conducted in the context of distance education. Distance education, as described by Willis (1994), is an educational format in which the learner and teacher are separated. In the past and in the present, distance learning has been conducted primarily by using correspondence and print materials. In more recent years distance educational communication has also been conducted via many other media or a combination of media, such as audio and video recordings, email, teleconferencing, video conferencing, computer modems, videodisk, compressed video, fax, computer assisted instruction, multimedia, radio and television broadcasting and the Internet (Willis, 1994). This study used the medium of computer-mediated video teleconferencing.

In this investigation, elementary age students experienced distance education/learning. The major distinguishing criterion of distance education is either geographic or temporal distance (Moore, 1990). The learner and the instructor may be separated by geographic location. Separation in time may also be a component of distance education. Education proceeds in the customary way, with student/instructor interactions. Student/instructor interaction opportunities have been provided to promote and evaluate student learning, using medium to compensate for the

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separation. In this study, both of the criteria described by Moore were met.

Video Teleconferencing via ISDN.

ISDN video conferencing has some unique technological characteristics. For a concise description of video teleconferencing technology I turn to McAteer (1994).

> A computer-linked camera captures images. A video processor digitizes and compresses the video images. The images then travel over a computer network. The accompanying audio signal typically travels over a telephone line or through the existing network to participants' modem-equipped P. C. s. (p.67)

Computer-mediated video teleconferencing using Integrated Services Digital Network (ISDN) was chosen for use in this study due to the recent widespread availability of this affordable technology. The transmitted images are not quite so good as high-definition television. That level of quality requires optical fibers for transmission, which will not be fully available for another decade or two.

The use of video teleconferencing is now practical for a wide range of users. One of the practical contributions of this investigation is that it includes information on children and teachers' use of Proshare (desktop video teleconferencing software). Proshare software allows the

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collaborative construction of joint notebooks by participants in Colorado and New Jersey.

Educational Applications of Technology and Collaboration

David Barr (1990), reviewing technologies current five years ago, peered into his "crystal ball" and forecast that "The convergence of computer, video and information technologies promises to help reform the education process" (p. 93). ISDN video teleconferencing was not one of the technologies Barr reviewed. Could ISDN video teleconferencing be a part of this reform? What will the role of teachers be while their students are interacting with their monitors?

Recently, Kerry Odell (1994) forecast that teachers will change, and that they will function as learning facilitators, adept at accessing information and "less hesitant to adopt new instructional technology" (p. 5). He also predicted that "distance learning will be commonplace" (p.5). But in what ways will distance learning become commonplace? Whittington considers this question and others. In 1994 Susie Whittington contemplated the future and asked:

> What can we achieve with communications technology? What are the possibilities for post secondary education, including graduate-level teaching, secondary teaching, or team teaching? What potential does this medium offer for regional research, for outreach and extension, for international programs, for inservice, for reaching

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> nontraditional audiences, for meetings, and for other collaborative efforts? (p. 17)

This investigation responds to the call for collaborative efforts in the educational use of communications technology by Whittington (1994) and Linn et al., (1996).

Video Teleconferencing Studies with Data.

In 1994 Wilson and Mosher reported initial findings from a pilot study using ISDN video teleconferencing capabilities. They created a model for a "virtual classroom," which they named Interactive Multimedia Distance Learning (IMDL). This model

> ...combined the rich communication capabilities of 2-way video teleconferencing with real time, synchronous data communications for sharing of computer application 'events' between workstations. The level of interaction is quite high and the environment offers the possibility of sharing between teacher and students and students with their peers. (p.32)

Wilson and Mosher (1993) indicated that students and teachers had the same databases and software applications in their desktop workstations. Students could work on-line or on their own. Teachers lectured or led students through exercises performed at their workstations. Students could engage in cooperative learning, sharing their work with other participants and receiving or giving feedback.

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In 1993 Wilson and Mosher conducted a pilot study. They neglected to report the number of subjects in their pilot, but they did report the various locations of the participants. The instructor was in Ohio, while the students were in Texas, Illinois, and New Jersey. The authors did gather feedback and categorized responses in terms of the affect reflected. They received positive feedback on the experience, with students enjoying the experience, the user interface and the software tools. Fear of technology was also reported, with the students feeling quite intimidated by the technology and anticipating a need for further help before they could use the technology. The authors concluded that the costs of their multimedia computer-based technology were dropping rapidly due to heavy competition and collaboration between cable and phone companies. The findings indicated that the described technology had not yet become 'transparent' to the users, which must occur so that the focus can shift to the user, away from the medium (Marlow, 1993). This study described the technology well. However, the research design needed to be improved, with full description of subjects, methods and analysis so that replication could be possible.

How can video teleconferencing best be implemented in a classroom environment? Marlow (1993) drew some conclusions concerning video teleconferencing based on seven case studies. He suggested that planning video teleconferencing is most successful when: it fills a critical human need, the

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"audience's" needs are considered, advance planning is provided, participants rehearse, systems are "humanizing" (requiring participation and feedback) and the system is flexible.

Value of Partnerships in Science Education

This section is devoted to discussing current literature on partnerships formed to improve science education. Linn, Songer and Eylon (1996) have articulated the value of collaborative research in science education. In examining current trends in understanding opportunity and disposition to learn science, they report shifts and convergences in the views of educational technologists, researchers, cognitive scientists, curriculum developers, college faculty who prepare science teachers, school administrators and teachers, and natural scientists and policy makers. Partnership studies usually involve researching both learning and instruction.

In addressing themselves to the larger issue of stereotyping of scientists, Finson, Beaver, and Cramond (1995) recommended expansion of children's contact with scientists. They elaborated that "these experiences should provide exposure to a variety of role models, including female scientists, scientists representing a larger array of cultures, and scientists conducting research in field as well as laboratory settings" (p. 201). Note that the video teleconferencing technology used for the context in this

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research makes such expanded experience with scientists readily available to elementary age children. With the expansion of ISDN technology across the world it has become possible to include far more variety in the classroom. For example, children can visit remote museums, peer through electron microscopes, look at satellite images of the earth, and go on field trips to places such as NASA.

In the spirit of contemporary views on effective science education and learning research, this educational psychology investigation has been conducted using a collaborative group including students, several natural scientists/technologists, two elementary teachers, and a researcher. As the teachers and scientists developed and delivered science instruction using computer-mediated video teleconferencing, I studied the children's science learning and epistemological beliefs.

Project Pearl.

Project PEARL (Public Electronic Access to Resources for Learning) is a prototype ISDN network that provides the capability for Electronic Field Trips to schools (Nahory, Harbison, Wullert & Gilchrist, 1995). In this study PEARL provided computer-mediated video teleconferencing linkage between Bellcore scientists, NASA and a Colorado elementary classroom. The Colorado classroom was equipped according to technological specifications provided by Project PEARL (see Chapter III for details). Project PEARL scientists collaborated with the classroom teachers in providing science instruction.

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Assessment

In this section literature on using children’s drawings as sources of information is reviewed. I begin with a general discussion on drawings and cautions for the development and reliability of drawing instruments. Next, the Draw-a-Scientist-Test (DAST) is discussed in detail, including topics such as reliability, factors affecting DAST, and validity.

Drawings as Data Sources.

A problem posed in research conducted with elementary age children is how to detect their knowledge despite their language limitations. There are various methods used by researchers in the past to elicit information from children. Some examples of these are interviews such as those used by researchers following Piagetian traditions, behavioral checklists, task-performance analyses, drawings, and oral questionnaires. Although all of these methods result in some usable data, the most comprehensive information on children's perceptions, attitudes and reasoning seems to result from triangulation of various methods. Hence, in this investigation the data gathering methods included drawings, semi-structured interviews and oral questionnaires.

There is extensive literature on children's drawings, and on the specific problems encountered in gathering data in this way. The following pertinent drawing research reviewed

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in this section is rooted in the "Draw a Man" test, currently in widespread use as a kindergarten readiness test.

Development and Reliability.

For some current developmental information on the psychology of children's drawings, and for some cautions on the reliability of children's drawings, I will describe work by Thomas and Silk (1990). Thomas and Silk reported on the reliability of the Draw-a-Man test. In their analysis of reliability, Thomas and Silk found reliability to be good in terms of inter-rater agreement with one drawing per child. However, reliability across drawings from the same subject was less, as children varied their drawings spontaneously and frequently. Thus, relying exclusively on analysis of children's drawings for information presents problems.

These authors evaluated Piaget's theory of children's drawing and concluded that it underestimated children's knowledge. First, Thomas and Silk (1990) argued that Piaget simply incorporated into his theory of cognitive development Luquet's view of drawing. Luquet described drawing as an attempt to represent the real world based on a 'mental image' (Piaget & Inhelder, 1969). Second, Piaget's theory did not deal with the problems of organization and procedure faced by a child who is creating a drawing. Thomas & Silk (1990) indicated that

> The shift from viewing drawings as a "print-out" of mental contents to considering them as constructions whose final form depends crucially on the procedures

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> used to produce them has been one of the most important recent developments in the study of children's drawings. (p. 32)

Taking this caution into account, children who produced drawings for this investigation were also been invited to elaborate verbally on their work. The notion here was that the children then had an opportunity to indicate procedural difficulties they may have encountered and to articulate their thinking in an additional mode of communication, thus allowing the children multiple opportunities to convey their responses and reasoning. Neither the drawing nor the interview alone could provide as much information about the children's understanding of science as the combination of methodologies. This process provided a sensitive assessment of children's understanding, in a stereotypic/script representation of how science is conducted.

DAST.

For precedents in using drawings to gather information about children's knowledge, I turn to the literature on The Draw-a-Scientist-Test (DAST; Chambers, 1983). The DAST uses children's drawings to elicit information from children concerning stereotypical knowledge of scientists. Both the DAST's simple procedure for acquiring drawings and the DAST's approach to scoring drawings based on specific elements drawn from literature served as precedents for this investigation.

David Chambers (1983), building on the Draw-a-Man literature, designed the Draw-a-Scientist Test (DAST) to

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identify the age at which children manifest 'standard' images of scientists. In a study which lasted 11 years, from 1966 to 1977, Chambers (1983) and 81 undergraduate assistants analyzed the drawings of 4,807 children. With no prior discussion the children were asked by their regular teacher to "Draw a picture of a scientist" (p. 258). A control group of 912 children were asked to "draw a person" (p. 258).

A 'standard' image of a scientist was determined in advance. Seven elements, partially based on literature, were scored as being present if they appeared fully or in part. Multiple indicators in the same category counted as one. The seven elements were:

1. Lab coat (usually but not necessarily white).
2. Eyeglasses.
3. Facial growth of hair (including beards, mustaches, or abnormally long sideburns).
4. Symbols of research: scientific instruments and laboratory equipment of any kind.
5. Symbols of knowledge: principally books and filing cabinets.
6. Technology: the "products" of science.
7. Relevant captions: formulae, taxonomic classification, the "eureka"! syndrome, etc. (p.260)

Chambers (1983) found that older, wealthier children had stronger stereotypes. Children with higher intelligence scores produced stereotypes younger. Only girls drew women scientists (note the inherent gender bias; girls' drawings

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would automatically be scored lower based on the non-inclusion of element number three). Chambers (1983) arrived at two major conclusions: first, that the stereotypic image of the scientist exists at the elementary school level, and second, that stereotypes gain in strength as children mature.

DAST has both strengths and weaknesses when used for identifying stereotypes in young children. The major strengths of the DAST are: the lack of dependence on verbal skill, making it useful for young children and non-English speaking people, 2) the grounding in the Draw-a-Man-test, and 3) the low cost and ease of administration. The major weaknesses of the DAST is that it may be difficult to interpret, thus it is better used in constructing hypotheses than in testing hypotheses (Chambers, 1983). Due to the weakness described, I did not use children's drawing as a stand-alone instrument in this study, but instead I used children's drawings to supplement interviews.

Reliability of DAST.

In this section I describe DAST research, including an approach to coding that is used for interrater agreement in this investigation. Schibeci and Sorenson (1983) reported on the reliability of the DAST when used with elementary school children. Schibeci and Sorenson (1983) used two coders who discussed the criterion for scoring prior to coding. A simple Pearson product-moment correlation was used as the index of agreement. The researchers drew their sample from two Australian elementary schools. One was rural, with a

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a black student population (n = 340), the other was urban and had a white student population (n = 4762). They concluded that the DAST yields a reliable global score, with particular indicators less reliable. Higher SES children produced more indicators.

The DAST advantages reported were:

1. no reading or writing required
2. quick administration
3. minimizes "socially-desirable" responses
4. analysis time required for coding, scoring and analyzing responses similar to semantic differential instruments or Likert scales. (p. 17)

Factors Affecting DAST.

In an Irish study by Maoldomhnaigh and Hunt (1988), gender differences were highlighted in the DAST scores. Their sample of 76 fifth graders was evenly divided among boys and girls. The girls' scores had a larger range. In addition, as in Chamber's (1983) original study, only girls drew women scientists, and more of them in their second drawing (demonstrating Thomas and Silk's (1990) point that spontaneous variation is likely to be present when children produce multiple drawings). This research reported adequate global inter-rater agreement. The element 'Technology; the products of science' yielded the poorest interrater agreement.

The present investigation is based on cautions and information from the preceding literature. An attempt has

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been made to define elements categories clearly to maximize inter-rater agreement while accepting variety in the actual drawings.

Refinements of the DAST Test.

Various empirical studies produced pertinent refinements in the DAST test. Reviews of two of these follow: the first describes the development of a checklist for the DAST, the second offers researchers cautions to prevent bias.

In the first study, Finson, Beaver, and Cramond (1995) developed and field tested a checklist to be used with the Draw-a-Scientist-Test. Finson, Beaver and Cramond dubbed their checklist for scoring drawings of scientists the DAST-C. Their multiple-measures method of data gathering influenced the data gathering methods selected in this investigation. The researchers found the checklist was effective in detecting perceptions of scientists. Thus, a checklist for the "Processes of Science" is used for organizing a semi-structured interview into quantitative data for this investigation (see Appendix E for a copy of this checklist).

Finson and colleagues collected children's drawings of scientists and used a checklist to score drawing elements and conducted structured interviews on adolescents' perception of scientists. However, their purpose was to compare results of checklist scores with interview scores, whereas in this investigation semi-structured interviews were used to

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elaborate on the information contained in children's drawings.

The DAST-C was field tested with a sample of 47 eighth graders. The checklist was found to present various advantages; it was time efficient, did not require subjects to use verbal skills, minimized socially desirable responses, and was easy to administer and to score.

The authors suggested that their checklist could be used for curriculum modification as well as for initial assessment and evaluation. They noted that the checklist increases efficiency in both the recording and the identification of elements, and renders data prepared for analysis.

In the second DAST refinement study, Symington and Spurling (1990) offer researchers bias cautions. Research indicates that relying on children's drawings alone for gathering information on their understanding may yield misleading results. Symington and Spurling (1990) suggested that data gathered solely from analysis of children's drawings may result in biased data. They reported that the stereotypical results generally found in using the Draw-a-Scientist-Test result from the instructions given. In support of their position, they presented contrasting examples of children's drawings elicited by two different instructions. The instruction "Draw a picture of a scientist" (p. 76), elicited a "known public stereotype" (p. 76), whereas conceptually rich and varied drawings were created in response to the instruction "Do a drawing which

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tells me what you know about scientists and their work" (p. 76). An instruction similar to this one was given to the students in an effort to elicit their knowledge of science processes for this investigation. In conclusion, Symington and Spurling (1990) cautioned that "researchers need to investigate how the children interpret the instructions they are given" (p. 77). Thus, in this investigation, children were encouraged to elaborate on their drawings verbally.

Epistemology

In the present study I investigate the relationship between children's epistemological beliefs and their understanding of science. In this section I review relevant literature on epistemology.

Psychologists and educators are increasingly interested in examining students' personal epistemological development and epistemological beliefs (Hofer & Pintrich, 1997). Areas of current interest include how individuals arrive at knowing, to what theories and beliefs individuals ascribe, and how the cognitive processes of thinking and reasoning may be influenced by personal epistemologies (Hofer & Pintrich, 1997).

In the past half-century there have been several research efforts into epistemology. Piaget (1929) introduced developmental psychologists to a connection between philosophy and psychology when he described his theory of intellectual development as 'genetic epistemology.' Following his lead, researchers into moral development were

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interested in investigating knowing, a revolutionary concept during this behaviorism dominated period (Kohlberg, 1969, 1971; Gilligan, 1982). In 1970, Perry studied college students and developed an influential theory of epistemological development.

There is a considerable body of research, based on Perry's initial work, on the influence of epistemological beliefs on the behavior of adults and adolescents. There has also been considerable epistemological research into adults' and young children's "theory of mind", a child's version of adults folk psychology, developed to explain behavior systematically (Wellman, 1990). Another term used for folk psychology is belief-desire psychology, and it has been proposed as a developmental point of departure prior leading to a cognitive science (Wellman, 1990). For example, folk psychology is believed to provide the basis for a universal folk biology (independent of culture of origin) providing adults with a personal view of endogenous biology (Hatano & Inagaki, 1997). However, this folk psychology, used for everyday explanations of the world, does not address itself to issues of truth. Epistemological concerns are expected to be a mature concern for the adult theory of mind. Chandler (1988) declared that, given the acceptance of the existence of an adult theory of mind, there are several controversies in the field.

(1) When, in the course of their development, do children first acquire something that might qualify as a

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> theory of mind; (2) assuming that mature theories of the mind do not arrive in the world full-blown, how soon after their first appearance do such theories begin to resemble those held by adults; and (3) how many meaningful different interim theories of mind separate those initial and final accomplishments? (p. 389)

There is as of yet little research that investigates elementary school age children's theory of mind. For a perspective on children's epistemological changes over time, I turn to Michael Chandler's 1987 and 1988 work. Chandler argued for an earlier emergence of relativistic epistemological views than that commonly suggested by epistemologists such as Perry (1970). That is, that epistemological relativism emerges in adulthood. Information on how people of different ages conceptualize knowing has been gleaned from developmental research on topics such as role-taking competence, empathy, and changes in person perception.

According to Chandler's analysis, school age children hold a realistic view, but are maturing. Children in early school age understand that in order to be knowledgeable, people need complete information, the complete truth is not necessarily obvious and partial data yields partial truth. They are aware that there may be external impediments to knowing the full truth. However, they assume that people with the same information will arrive at the same truth. They believe there is one universal truth to be discovered

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instead of individually constructed. They believe that when all the data are in, the truth will prevail.

Preadolescent children's epistemological beliefs generally tend to be objective in nature. An objectivist epistemology makes the following two assumptions: "(1) the world-as-it-is-in-itself (Goodman, 1976) is held to be directly knowable; and (2) the truth or falsity of any claim is assumed to depend solely upon its relation to a rock-bottom and unassailable foundation of facts" (Chandler, 1987, p. 145).

Chandler indicated that a period of epistemological confusion reigns between childhood and maturity, and that much of the strain of adolescent intellectual development can be attributed to the young person's struggle with a classic set of epistemological problems. Doubts about the nature of knowledge creep into the adolescent's view of the world, and with it an understanding that perhaps all knowledge is personal and thus subjective. Chandler identified this transition as marking the emergence of the truly constructivistic mind.

Although there appears to be agreement that children hold epistemological beliefs, there is little actual research on elementary school age children's epistemology and the impact of their beliefs on knowledge acquisition. There is a need for extending research on the components of epistemology in this age group (Smith, Houghton & Maclin, 1997).

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Recent research on epistemological beliefs and reasoning may be grouped into six general areas: (a) extending Perry's developmental sequence; (b) developing measurement tools to assess epistemological development; (c) investigating gender issues in ways of knowing; (d) researching how awareness of epistemology is embedded in reasoning and thinking processes; (e) assessing links between beliefs and cognitive processes; and (f) identifying dimensions of epistemological beliefs (Schommer, 1989, Schommer & Walker, 1995; Hofer & Pintrich, 1997). This study examined the epistemological beliefs of children, an age group which remains largely unexplored using Schommer's perspective.

Schommer's View of Epistemology.

In this section, Schommer's (1989, 1994c) theory of epistemology is described. According to Schommer's (1994c) cognitive view of multi-dimensional personal epistemology, personal epistemology can have many meanings:

> A review of the epistemic literature makes it apparent that 'personal epistemology' takes on different shades of meaning from study to study. Furthermore, conceptions of epistemological beliefs in cognitively-oriented research move away from the traditional philosophical inquiries which assume, true, universal and absolute knowledge. Instead, cognitive researchers focus on what individuals believe about the degree to which information is true, the organization of

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information, the acquisition of knowledge, and the justification of knowledge claims. (p. 294)

Schommer (1989) developed a questionnaire to measure personal epistemologies. Her original work suggested that five factors were salient (see Table 1). Schommer (1989)

Table 1

Schommer's Epistemological Dimensions

Epistemology Dimension	Continuum
1) Source of knowledge	From knowledge is handed down by omniscient authority to knowledge is reasoned out through objective and subjective means.
2) Certainty of knowledge	From knowledge is absolute to knowledge is constantly evolving.
3) Organization of knowledge	From knowledge is compartmentalized to knowledge is highly integrated and interwoven.
4) Control of learning	From ability to learn is genetically pre-determined to ability to learn is acquired through experience.
5) Speed of learning	From learning is quick or not-at-all to learning is a gradual process.

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reviewed prior research to provide construct validity for her hypothesized five epistemological dimensions for high school and college students.

The source of knowledge/omniscient authority concept is supported by literature that indicates the role of the learner in relationship to authority. For example, in research conducted by McDevitt (1990) the findings were that although mothers of elementary age children believed their children should ask questions to resolve confusion, children were reluctant to ask questions if the speaker was of higher status. Elementary children reported that a good listener sits quietly and does not interrupt the speaker (McDevitt, Spivey, Sheehan, Lennon, and Story, 1990). Traditional college students rarely (less than 15%) asked questions of their teacher/instructor (authority) whether for clarification or criticism. Non-traditional students were somewhat more likely to ask questions of their instructors (McDevitt, Sheehan and McMenamin, 1991). McDevitt et al.,(1991) concluded that the social status differences between the speaker and the listener were enough to result in question suppression. Implicit in this research is the importance of silence as a sign of respect before the source of knowledge, or the authority (for example, the teacher). This perceived social appropriateness could interfere with the development of independent reasoning.

Beliefs about the certainty of knowledge (certain knowledge) may influence interpretations of knowledge. In an

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interesting study by Schommer (1990), students were presented with passages to read that contained contradictory information and no concluding paragraph. Students were asked to write a concluding paragraph. These paragraphs were then classified according to the students' epistemological beliefs. Schommer (1992) reported that student belief in the certainty of knowledge led to distortion of received information in conformity with their beliefs.

Beliefs about the organization of knowledge (simple knowledge) may influence the integration of knowledge. Spiro, Coulson, Feltovich, and Anderson (1988) reported that medical students' beliefs in simple analogies led them to oversimplify information and thus they failed to recognize exceptions. These student compartmentalized their knowledge, to the detriment of their future patients, who would be better served by physicians who had an understanding of how various diseases might interweave within their future patients.

Dweck and Bempechamp's (1983) and Dweck and Leggett's 1988) research examined the belief that the learner can control learning (fixed ability). They reported that some children were 'fixed theorists,' believing that the ability to learn is innate. Other children were 'incremental theorists,' believing that intelligence could be improved and so they continued in their efforts to learn even when the task was difficult.

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Beliefs about the speed of learning (quick learning) influence persistence. Students who believed that learning must be quick or not at all did not persist in trying to solve mathematical problems (Schoenfeld, 1983, 1988; Schoenfeld & diSessa, 1990), nor in learning communications skills in foreign languages (Elbaum, Berg & Dodd, 1993, Horwitz, 1988). The less students believed in quick learning, the higher their Grade Point Average (Schommer, 1993).

In developing her theory of epistemology, Schommer conducted some interesting empirical studies, reported in this section. For example, in an experimental study, Schommer, Crouse and Rhodes (1992) replicated the factor structure of Schommer's (1989) epistemology questionnaire with a sample of 424 university students. Beliefs in externally controlled knowledge, quick learning, certain knowledge, and simple knowledge were measured.

In addition, the relationship between epistemological beliefs and reading comprehension was investigated. Regression analysis indicated that belief in simple knowledge was negatively associated with comprehension. Simple knowledge scores were almost as predictive of total test score, as was prior knowledge (consisting of more previous mathematical courses). Belief in simple knowledge was also negatively associated with an aspect of metacomprehension (over confidence). Belief in simple knowledge predicted students' overestimation of their comprehension. A path

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model indicated that study strategies may mediate the influence of simple knowledge beliefs on comprehension. Thus, educational efforts may prevail over personal epistemological orientations.

In the next two studies Schommer revised her questionnaire and focused on the development of epistemological beliefs among adolescents. In a cross sectional study, Schommer (1993) investigated the epistemological beliefs development of 1,182 secondary students and the relationships between these beliefs and academic performance. The epistemological questionnaire used in earlier studies with college age students was modified for use with high school age students. Factor analysis yielded a four factor structure, 1) simple knowledge, 2) certain knowledge, 3) innate ability and 4) quick learning. Test-retest reliability was .74, and inter-item reliabilities for items composing each scale ranged from .63 to .85.

Schommer found that some epistemological development occurred in high school, with beliefs in certain knowledge, simple knowledge and quick learning changing significantly from freshman to senior year. However, beliefs in fixed ability did not change over time, supporting Schommer's theoretic perspective on individual epistemological beliefs as more or less independent within a personal epistemic system.

Epistemological beliefs were found to predict GPA's, even after general intelligence (IQ scores) was taken into

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account. Schommer found that the "less students believed in quick learning (r=-.26), simple knowledge (r=-.20), certain knowledge (r=-.12) and fixed ability (r=-.15), the better were the GPAs that they earned" (p. 409).

In a 1997 longitudinal study, Schommer, Cavet, Garigliette, and Bajaj examined the development of epistemological beliefs in 69 secondary students. The epistemological beliefs questionnaire used for this study had been used in her previous research (Schommer, 1990; 1993; 1994a; 1994b; Schommer et al., 1992). The questionnaire was demonstrated to have predictive validity for comprehension, interpretation of information, integration of information and metacomprehension (Schommer, 1997).

Four factors were replicated consistently in these studies, malleability of learning ability, structure of knowledge, speed of learning and stability of knowledge. These four factors each included conceptual beliefs subsets: (a) malleability of learning subsets included "learn the first time", "can't learn how to learn", "success is unrelated to hard work", "the ability to learn is innate", and "concentrated effort is a waste of time"; (b) structure of knowledge subsets include "avoid ambiguity", "seek single answers", "avoid integration", "depend on authority"; (c) speed of learning subset was "quick learning"; (d) stability of knowledge subsets included "knowledge is certain" and "don't criticize authority" (Schommer et al., 1997, p. 39). The inter-item reliabilities for the items in each factor

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ranged from .63 to .85. Test-retest reliability over an eight week period was .70. Schommer's results indicated that, as students neared graduation, their epistemological beliefs matured. They were less likely than they had been to believe in fixed ability to learn, simple knowledge, quick learning, and certain knowledge. Schommer found that students who did not believe learning was quick had higher grade point averages. She also found a gender difference, with girls less likely to believe in quick learning. These results replicated earlier findings from a cross sectional study conducted by Schommer in 1993, and provide information on the development of epistemological beliefs.

Schommer et al. (1997) raised a question at the end of their paper. They asked, "How do these beliefs evolve?" The present study attempted to extended Schommer's work by investigating the epistemological beliefs of elementary school age children.

Epistemology Dimensions and Elements of the Processes of Science

In the following section the expected relationship between children's epistemological beliefs and their understanding of science is described in detail. Please see Appendix A for a table demonstrating the suggested relationship between Schommer's (1989) five dimensions of epistemology and the National Science Education Standards processes of science:

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1. Ask a question. The NSES describes this element as "Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world" (NSES, 1996, p. 123). I expected this element of the processes of science to be related to the following of Schommer's epistemology dimensions: (a) control of knowledge, (b) source of knowledge and (c) certainty of knowledge.

(a) The control of knowledge dimension extends from ability to learn is genetically pre-determined to ability to learn is acquired through experience. Research by Dweck et al.,(1988) on children's beliefs about intelligence is the basis for this dimension. They proposed that children may be fixed or incremental theorists concerning intelligence. Fixed theorists believe the ability to learn is fixed, and engage in helpless behaviors when tasks become difficult. Incremental theorists believe intelligence can be improved and so persist in the face of difficulty. I suggest that asking a question is likely to be perceived as a difficult task and thus children low in control of knowledge will score low in this ability.

(b) Source of knowledge extends from knowledge is handed down to knowledge is reasoned out through objective and subjective means. This dimension is partly based on McDevitt, Sheehan and McMenamin's (1991) research on student's beliefs about listening. McDevitt et al.'s

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research reported that some college students take a passive approach to listening, preferring to listen quietly without asking questions. The listening research was coupled with the epistemological categories of silence and received knowledge developed by Belenky, Clinchy, Goldberger & Tarule (1986) resulting in the concept that authority has the knowledge, and the rest of us should attend carefully in hopes of receiving knowledge. Thus, I expected that students scoring high in authority would score low in this science inquiry ability.

(c) Certainty of knowledge is presented as extending from <u>knowledge is absolute to knowledge is constantly evolving</u>. Schommer (1990) supported this concept with her own research on reading comprehension. She found that students who had strong beliefs in certain knowledge interpreted tentative knowledge as absolute. Posing original questions would be unnecessary if knowledge is absolute, thus I expected low scores in science questions from an absolutist orientation.

2. <u>Plan a simple investigation</u>. "Scientists use different types of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting)" (NSES, 1996, p. 123). This element of the processes of science is expected to be related to the following epistemology dimensions: (a)

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control of knowledge, (b) structure of knowledge and (c) speed of knowledge acquisition.

(a) Control of knowledge acquisition extends from ability to learn is genetically pre-determined to ability to learn is acquired through experience. (See element 1 above for an extended discussion of this element). Making a plan is a complex problem. Students who are fixed theorists are likely to give up on such a difficult task (Dweck & Bempechat, 1983). Thus, I expected low scores in planning for students with high control of learning.

(b) structure of knowledge (organization of knowledge) spreads from knowledge is compartmentalized to knowledge is highly integrated and interwoven. This dimension is founded on Anderson's (1984) view that low-achieving students store knowledge as unrelated facts, with no expectation that integration is a possibility. To plan an investigation, it is necessary to integrate process knowledge with the objectives of the study. Thus, I expected a student who scored high on structure to have difficulty forming a plan for an investigation.

(c) Speed of knowledge acquisition extends from learning is quick or not-at-all to learning is a gradual process. Schoenfeld's (1988) research on students' persistence in solving mathematical problems contributes to the definition of this dimension. He found that many high school students believed mathematics problems should be solved in 12 minutes or less. Some students quit after five or six minutes on a problem. Schommer (1993) found that the less students believed in quick learning, the higher the grade point average they earn. Thus, I expected that planning an investigation would require the view that learning is a gradual process, requiring persistence. Quick or not-at-all scorers are likely to score low on planning simple investigations.

3. Employ simple equipment. "Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses" (NSES, 1996, p. 123). I expected this element to be related to the structure of knowledge epistemology dimension.

Structure of knowledge is a dimension that goes from knowledge is compartmentalized to highly integrated and interwoven. Spiro et al.'s (1988) research with medical students provided the basis for this dimension. Spiro et al. found there was a tendency for students to take information and compartmentalize it instead of integrating it, thus failing to modify their schemata when modification should have occurred. Children need to integrate their understanding of their original question with their knowledge of available resources in order to make a plan for investigation that would include choosing appropriate instrumentation. Thus, I expected students with highly compartmentalized organization of knowledge to score low in use of equipment.

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4. Use data to construct a reasonable explanation. In the NSES this element is described as "Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations" (NSES, 1996, p. 123). I expected this element of the processes of science to be related to the following of Schommer's epistemology dimensions: (a) source of knowledge, (b) structure of knowledge and (c) speed of knowledge acquisition.

(a) Source of knowledge is a dimension of epistemology which extends from knowledge received from omniscient authority to knowledge is reasoned out. This dimension is founded on Perry's (1970) theory of college students' beliefs about the nature of knowledge. He posited nine positions of change. During the first stage (dualism), students see knowledge as right or wrong. Authorities know the answers. By the final stage (commitment), students see that there are multiple possibilities for knowledge. They also know that they can commit to some ideas as an ongoing process of creating their personal lifestyle. Children must be aware that it is possible for authorities to be wrong before they would even consider gathering evidence to challenge assumptions. Therefore, I expected a score high in reasoned knowledge would be matched by a high score in using data to construct an explanation.

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(b) In the structure of knowledge dimension, <u>knowledge ranges from compartmentalized to highly integrated and interwoven</u> (See elements 2 and 3 above for extended background discussion). Students are likely to have high integration scores in order to score high on constructing explanations from evidence because the collecting together of data, and consolidating it into a reasonable explanation, requires that a child engage in synthesis. Thus an implicit constructivistic process is influential in understanding this element of science. I expected that a high score in the structure of knowledge dimension would result in a high score in using data to construct an explanation.

(c) The speed of knowledge acquisition dimension extends from <u>learning is quick or not-at-all to learning is a gradual process</u> (See element 2 for an extended discussion of speed of knowledge). Investigations require extended effort, and so I expected that a student would have low scores in this element if learning was expected to be quick or not at all.

5. <u>Apply Technology</u>. "Tools used by students and teachers to conduct inquiry and understand science" (NSES, 1996, p. 24). I expected this element to be related to certainty of knowledge.

The certainty of knowledge dimension extends from <u>knowledge is absolute to knowledge is constantly evolving</u> (See element 1 for an extended discussion of certainty of

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knowledge). Implicit in the use of tools for inquiry is the authority to do so. If everything is already known, then inquiry is unnecessary. Students who score high in the view that knowledge is constantly evolving are likely to score high in technology because tools are used to gain more knowledge.

6. Communicate investigations and explanations. "Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations" (NSES, 1996, p. 123). I expected that this element of the processes of science was related to the structure of knowledge.

Structure of knowledge is a dimension that contains the continuum from knowledge is compartmentalized to knowledge is highly integrated and interwoven (for an extended discussion of structure of knowledge see element 3 above). Integration of the investigations and explanations needs to be achieved in order to be able to communicate what was done coherently. For example, if a child gathers data about water but fails to describe her investigative method, she will be left with 'facts' that cannot be replicated. I expected students who scored high in integration would score high in communicating their investigations and explanations.

7. View science as a human task. The NSES describes this element as "Science is a human endeavor" (NSES, 1996, p. 141). This element is expected to be related to the following

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epistemology dimensions: (a) control of knowledge and (b) source of knowledge.

(a) The control of knowledge acquisition dimension extends from ability to learn is genetically predetermined to ability to learn is acquired through experience (for an extended discussion of this dimension see element 1 above). It is expected that a student scoring high in learning through experience would be more likely to acknowledge that science is a purposeful endeavor and so score high in this section. If a child believes that the ability to learn is genetically predetermined then he or she might not engage in the necessary steps to accomplish an investigation, viewing them as pointless.

(b) The source of knowledge epistemology dimension continues from omniscient authority sources to reasoned out knowledge (for an extended discussion on source of knowledge see element 1 and 4 above). I expected that students higher in reasoning would score high in this element. I also expected that there could be some confounding in this element and in this dimension due to the age of the students. Many people look like authorities to eight year olds, and young children may perceive that they receive most of their information from people (rather than books or their own constructions, for example).

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8. Check each others' work. "Scientists review and ask questions about the results of other scientists' work" (NSES, 1996, p. 123). I expected this element to be related to the following dimensions: (a) source of knowledge and (b) certainty of knowledge.

(a) The source of knowledge dimension extends from omniscient authority sources to reasoned out knowledge (for an extended discussion on source of knowledge see elements 1 and 4 above). Because this element implies that there is no single authority, high scores in the understanding that knowledge is reasoned out would be expected to correlate with high scores in this element, where scientists review each other's work.

(b) The certainty of knowledge dimension goes from knowledge is absolute to knowledge is tentative and constantly evolving (see element 1 for an extended discussion of the certainty of knowledge). If knowledge is absolute, then there is no need to check other's work, nor to engage in replication because we already have the answers. I predicted that a student who believes that knowledge is constantly growing and adjusting due to new information would score high in this element.

Conclusion

In this chapter an attempt was made to describe the need for this study based on historical shifts in perspectives on science education and the social press for improved science

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education. Technology and collaboration in instruction were described as prescriptions from the science education literature for the improvement of science education, and are included in the context of this study. The difficulty of assessing children's understanding of science was discussed, the construct was defined on the basis of standards, and a methodology to investigate elementary children's epistemological beliefs and their hypothesized influence on children's understanding of science was formulated. Lastly, Schommer's theory of multi-dimensional epistemology was described in detail.

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CHAPTER III

METHODS AND PROCEDURES

This study was a naturalistic field experiment with pre- and post-measures. Although there are many practical constraints in a field study, this method was chosen as most appropriate because the context of the study, a distance education application, required a functioning classroom. This investigation was motivated by the absence of literature on the epistemology of children using computer mediated video teleconferencing to learn science from scientists in their classroom. This opportunity for teachers to collaborate in this manner with scientists at a distance was made possible through project PEARL. Integrating experts into the classroom curriculum via distance was affordable, but did require the fixed installation of an ISDN line and the use of computer equipment.

This chapter provides a description of the children who were the participants in this study and a description of the school where the study was located. The classroom habitat is discussed, including the technology required for video teleconferencing. The participating teachers' philosophy of instruction is reported. Instruments and procedures used to

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gather data on children's epistemology and science understanding are described. The chapter closes with a description of the methods for data analysis.

Description of Research Participants and Context of the Investigation

The school in this study was located in Greeley, a town with a population of 69,500 on the plains of northeastern Colorado. The school was a laboratory school, associated with the University of Northern Colorado (UNC). The mission of the school was to

1. model an effective, student-centered teaching/learning environment;
2. be an integral component of UNC's teacher education role and mission
3. be a primary resource to which Colorado educators turn for support with innovative renewal (University of Northern Colorado Laboratory School, 1997, p. 1).

The UNC Laboratory School was partially funded by the university. Parents paid $630.00 per year (1995-96) as tuition. Approximately 10% of the student population was on tuition waver due to low family income. Twenty seven percent of the student population belonged to ethnic minority groups. There was a total student enrollment of 575, of which 151 were elementary school students.

The Thinking, Learning and Caring (TLC) community classroom used in this study was chosen for several reasons:

1. the receptiveness of the students and parents.

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2. the composition of the classroom, which included students from second, third and fourth grades.
3. the receptiveness of the teachers.
4. the support of the administration.
5. the students were accustomed to having visiting adults in their classroom and habituated quickly to the presence of a researcher.
6. their parents may have been familiar educational research because this is a laboratory school.
7. the range in age of the students in this classroom, while maintaining the same teachers, afforded an opportunity to explore developmental differences in this study.
8. the technology required hard-wiring, an ISDN line into the classroom, which the administration was willing to allow.

Project PEARL required that schools provide the following desktop video equipment for participation:

1. ISDN line
2. Personal computer (Pentium)
3. INTEL Proshare (video electronics cards, cameras and screen sharing software).

This classroom was equipped for project PEARL, and was viewed as the children's habitat, or their learning context.

In this study, the children, their classroom teachers and the researcher were located in Colorado, thus geographically separated from the scientist, located in a

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laboratory in New Jersey. The participants communicated via computer-mediated video teleconferencing technology, transmitted over ISDN lines. The temporal distance was minimal, with a slight lag (limited to seconds) between audio/visual transmission and response. The software included a screen sharing application, which allowed local and remote participants to build a joint notebook, with minimal wait time (Nahory, Harbison, Wullert, & Gilchrist, 1995). For example, to assist in learning each other's names, the children, the teachers and the scientists built a directory of the participants including video 'snapshots' of the New Jersey participants and the Colorado participants, which were entered interactively and then saved as files available on both the local and remote computer.

This elementary classroom was named Thinking, Learning, Caring Community (TLC). There were 34 students, 21 girls and 13 boys. There were four children with varying levels of hearing impairment.

Two master teachers taught full-time, and one student teacher was present for the semester of the investigation. A tutor-interpreter was present to assist the hearing impaired students. The communication method used with these hearing impaired students was Signing Exact English (SEE). The two teachers not only taught in this classroom, but also conducted workshops as inservices for other teachers as part of their dissemination responsibilities to the university.

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The teachers conducted their classroom using innovative teaching methods. They shared a well developed and clearly articulated philosophy of teaching. One of the teachers, Teri Beaver (1995), wrote:

> The process of becoming highly literate is complex and lifelong. It consists of patterns and cycles and is never complete. But we can begin by using our limited understanding of it--that it takes awareness and willingness on the part of the learner and an environment which provides modeling, support, time and feedback. For our students, we must become facilitators of the process. (p. 3)

These teachers collaborated fully with the scientists from project PEARL in creating science lessons for their classroom.

Highlights from Video Teleconferencing Science Lessons.

In this section I summarize the actual implementation of the video teleconferencing science lessons. A description of how this application of video teleconferencing instruction was conducted is provided. The respective roles of scientists, teachers, students and researcher are identified.

The scientists arrived in the classroom via video teleconferencing in response to an invitation from the teachers, and served as science domain experts. It is important to note that the scientists entered the classroom

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with some concepts that they believed children could derive from their distance learning experience. First of all, they suggested directly to the children the idea that "We are all scientists." They proposed that what scientists can do, children can do. The following is a listing of what the scientists indicate children can do:

1. Formulate questions.
2. Think about what could be answers?
3. Guess the answer (a very imaginative, creative process).
4. Do experiments.
5. Find out that the guess was wrong. It is OK to be wrong, it simply means we are working in the unknown.
6. Ask new questions based on the results (Nahory, personal communication, June 14, 1998).

Throughout the intervention, the teachers collaborated in providing science instruction, continued to provide normal classroom management and supplied in-between video teleconferencing session instruction. This researcher served both as classroom technologist, installing and maintaining the equipment, and as scheduling coordinator between the teachers and scientists.

The technology was adapted for this classroom by using a hand-held mike and a television screen to amplify the size of the computer screen. Although there was some concern that the children might have difficulty concentrating due to

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habituation to television screens as entertainment, this did not prove to be a problem, and the children maintained their focused attention on the scientists.

Initially the scientists were introduced, as science experts, to the class in one large group. In later sessions, the normal pedagogical structure of the classroom was resumed during the video teleconferencing instruction. The class was divided into two large groups of students, known as the 'mountains' and the 'plains' groups. There were approximately the same number of students in each group, working with one classroom teacher. When engaged in hands-on activities, small cooperative groups clustered within these larger class structures.

The students were expected to take an active role in the process of learning. The activities the children engaged in during this instruction were varied. The children

1. observed nature while on a class field trip, and developed a large group question.
2. discussed their question with scientists via video teleconferencing,
2. hypothesized a possible explanation,
3. planned investigations to test their hypothesis, in cooperative groups,
4. implemented their plan,
5. recorded their findings,
6. Discussed their findings with Dr. Bob.

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The science lessons were developed collaboratively by the teachers and scientists in video teleconferencing planning sessions. In order to conduct experiments together, the teachers and scientists collaborated in providing the same materials at both the local and remote location, so the children and the scientists could investigate and discuss observations together. Included were materials such as pails of water, objects of different shapes and composition, and thermometers.

In planning their collaborative lessons, the teachers and scientists tried to make the lessons meaningful by having the children's interests guide the lessons. For example, the children observed a partially frozen lake while on a field trip with their teachers. Then they formulated the question "Why does ice float?" The teachers and a physicist (hereafter referred to by the children's name for him, 'Dr. Bob') used this question to commence a series of lessons on the properties of water. The range of topics began with ice and, in interaction with the children, evolved to include the flotation of objects on water, changes in water when the temperature fluctuates, and the density and molecular structure of water.

The following description of a series of lesson highlights is provided as an example of the pedagogical sequence in which this class engaged. First, the children formulated a hypothesis, tested it and rejected it. Second, they discovered the difference between frozen and liquid

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water. Lastly, they formulated a new, open question, and then reverted to their original hypothesis.

In one of the water lessons the children hypothesized various explanations for the flotation of ice in interactive discussions that included the teachers and Dr. Bob. The children hypothesized that the shape of an object might influence whether it floated or not. The teachers then provided the cooperative groups with clay, pails of water with floating ice cubes. The teachers asked the children, "Can you make an object that sinks float? The children took a lump of clay rolled into a ball about the size of an ice cube, dropped it into a beaker of water and watched it sink to the bottom. Next, they shaped the lump into a flatish boat-like shape and discovered that it floated. Then some of the children hypothesized that there might be air trapped in the ice and the clay, which would cause them to float. In discussing why this difference occurred, Dr. Bob introduced the concept of density. And from that discussion, several questions emerged: Why is there a different density in ice? What changes in the water when it freezes? What is water made out of? The lesson ended with these questions pending.

In the next video teleconferencing lesson, Dr. Bob introduced the concept of a molecule. He sent the class a chemical diagram of a water molecule over their shared computer notebook (this graphic of H_2O made quite an impression. It appeared in some of the posttest drawings; see Appendix I for an example). Then he posed the question:

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'What would you do if you were a molecule in the water?' Dr. Bob had the children pretend to be water molecules. They stood together in a tight group with their bodies representing oxygen atoms and their arms extended with fists representing hydrogen atoms. The children-molecules were told by Dr. Bob that they were being heated, so they had to jiggle about, jostle around, bumping into each other which caused them to pull away from each other until they pretend-vaporized. Finally, Dr. Bob ended the lesson by asking the molecule-children, "What might happen if you freeze?"

For a week the children pondered the question, but did not think of making a pattern with the water molecules. At this point an example of Vygotskyan (1962) scaffolding occurred. Dr. Bob sent the class a picture of a crystal structure in hexagonal shapes. Then a classroom teacher encouraged six children to get back into their water molecule roles, standing with arms extended. To simulate freezing, the six children held hands with their arms extended stiffly. Then the children-ice-molecules 'melted,' turning loose of each others hands and jostling around. The children engaged in several 'freeze' and 'melt' repetitions. Then their teacher asked them if they noticed that they required more floor space when they were 'frozen'. Suddenly, the children did observe that when they were loose they could crowd closer together. Their teacher said to them "That is density". In an example of an "aha" experience, the child grasped the

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concept of density, and the children-molecules 'froze' and 'melted' several more times.

A wonderful example of the tenacity of misconceptions was now demonstrated as the children questioned what might be in the holes in the hexagon, and returned to their original hypothesis of air causing flotation. They asked, "Could it be air? What is the size of the hole?" The lesson ended with this identification of the next question.

In a post-lesson de-briefing between the teachers and the scientists, the teachers noted that they were initially somewhat skeptical as to the potential value of video teleconferencing science instruction. However, they now indicated that they were pleased with the outcome, as they believed the class would not have asked the questions that were asked without the intervention of the scientists.

Sample.

All 34 students in the TLC were asked to participate in this study. Consent forms were sent home with all the children (n = 34) in the class. Initially, fifteen consent forms were returned. Consent forms and an explanatory letter were sent home three more times with the children who had not returned consent forms. A total of twenty four consent forms were returned. Of these potential subjects, one was unusable due to the child's random answers to the epistemology questions and another child failed to complete the science posttest A. Thus the number of children who participated as subjects in the major part of this study was 22. In the

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major part of the study, the children ranged in age from seven years, 10 months to eleven years, 2 months, with a mean of nine years, 6.6 months. There were 12 girls in the study and 10 boys. One additional child failed to complete the science posttest B. In the section which compared science posttest A with science posttest B, there were 21 subjects. In this part of the study there were 11 girls and 10 boys. The age range was the same as in the major part of the study, but the mean differed, at nine years, 5.5 months.

Instruments, Data Collection and Analysis

In this section the epistemology instrument and the science understanding instruments are described. Next, the procedures followed during data collection are reported. Finally, the original analysis plans are presented.

Epistemology Instrument.

Schommer's (1989) epistemology questionnaire has been used extensively in epistemological research with college students and high school students. Work on modifying it for research with younger ages is in progress (Schommer, 1995). In Table 1 (p. 57), Schommer's five dimensions are described.

Schommer's Epistemological Questionnaire Categories, including positive and negative valence for each item, as shown in Appendix B, have been used as the basis for developing an epistemology instrument for children. Schommer has recently modified her questionnaire for use with middle school age children, but has not yet produced reliability and

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validity figures for children under age eleven (Schommer, 1995). An explicitly worded five-dimensional epistemology questionnaire modified from Schommer's work (1989, 1990, 1995) was used for this study. The questionnaire has 20 items. Ten of the items used were recommended by Schommer for use in interviewing younger children. The other items were selected from her middle school questionnaire with two major criteria in mind: simplicity of wording and inclusion of four items on each conceptual dimension. Seven items had a negative valence (eliciting answers in the opposite direction from the rest of the study), to control for response effects.

Of all the instruments used in this study, the epistemology instrument restricts response choice the most. Although Schommer's (1997) most recent version uses a five point Likert scale for measuring agreement, this study incorporates a four point Likert scale (see Appendix C) to avoid neutral answers. The graphic four point Likert scale used to elicit the child's level of agreement presented the following choices: 1. No, 2. Sort of no, 3. Sort of yes, and 4. Yes (see Appendix D).

This modified epistemology questionnaire was individually administered. The questionnaire was administered twice, with a four week interval (the span of the intervention) between administrations. Items were read aloud to the child, who responded by pointing to the face that best reflected his or her response. Children's

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responses were treated as ordinal data from 1 to 4. Although no significant change in epistemology scores was anticipated over this brief time period, correlations between pre- and posttest A were calculated to report test-retest stability. See Table 2 (p. 89), for Epistemology Instrumentation.

Science Understanding Instrument.

As I described in Chapter Two, I based the measure of children's understanding of the processes of science for this study on Chamber's (1983) research on the Draw-a-Scientist-Test (DAST).

In this study the classroom teachers asked the children to "Do a drawing which tells me what you know about scientists and their work." This test was group administered twice, prior to and after the video teleconferencing lessons with the scientists. Next, students in this study were individually interviewed to elicit the meaning of their drawings in their own words. The semi-structured interviews were videotaped.

The questions used for the semi-structured interviews may be found in Appendix E. The questions were only used when the elements of science were not obvious in the drawings nor spontaneously volunteered by the student in describing the drawing. Thus, although the same queries were used when necessary, not all students received the prompts. Both the drawings and the interviews were interpreted as the children's understanding of the processes of science. These

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Table 2

Epistemology Instrumentation

Instrument	Data Source	Type of Analysis
Epistemology Questionnaire.	Children's responses to epistemology questionnaire/ 15 item test measuring degree of agreement on a four-point Likert scale. Scores were yielded on 5 dimensions. Administered twice, at pre & post phase.	Stability measure reported as test-retest correlations on the five dimensions.

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were scored according to the eight elements derived from the NSES (1996): 'elements' of the processes of science. These elements were:

1. Ask a question.
2. Plan a simple investigation.
3. Employ simple equipment.
4. Use data to construct a reasonable explanation.
5. Apply technology.
6. Communicate investigations and explanations.
7. View science as a human task.
8. Check each other's work.

The score sheets contained two score blanks for each element. The first was for drawings and the second for the interview. The presence of elements of the processes of science was scored as 1 and the absence as 0 in the score column. Prompts for the interview were in the second column. Multiple manifestations of an element in one category still counted as one, as they represented the understanding of only one element. See Appendix E for a copy of the score sheet and examples of the kinds of data which would be scored positively.

In the posttest B students looked at my drawing which included all eight elements of the processes of science (See Appendix F), thus offering students an identical visual stimulus. Then the same semi-structured interview was conducted. I planned to use this alternative measure of science understanding if the drawings by the children proved

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too variable to arrive at acceptable interrater agreement. Data from this interview were scored by the raters using the method described above, except that all source data were exclusively verbal.

The processes of science interview were repeated three times, with a four week interval between the pre-test and the posttest A. The posttest B occurred the day after the posttest A (see Table 3, pp. 92-93). The pre-test, posttest A and posttest B drawing and interview raw data on processes of science were scored by two independent raters, trained using pilot study data. A composite score was produced from the ordinal data for processes of science. For example, three elements of science might appear in the drawing, and two in the interview, resulting in a composite score of five. Interrater reliability was reported using Cohen's (1960) Kappa.

Procedures

Because special equipment and hard wiring were required (ISDN line, computers, video conferencing), one intact elementary classroom was selected to participate. A pilot test was conducted with approximately 10 children in the adjacent classroom to determine if the instruments or procedures needed to be modified. There were 22 students who were participants in this study.

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Table 3

Processes of Science Study Instrumentation

Instrument	Data Source	Type of Analysis
Processes of science Drawing/interview.	Processes of science drawings (group administered) and semi-structured interviews (individual), composite score = total number of elements (out of a possible eight). Administered twice, at pre and post test phase a.	Two independent raters scoreed pre and posttests time-blind. Interrater agreement reported using Cohen's (1960) Kappa.
Drawing and picture.	Data from post test a and post test phase b.	

(table continues)

Instrument	Data Source	Type of Analysis
Drawing and picture.	Data from post test a and post test b	Two independent raters scored pre and posttests time-blind. Interrater agreement reported using Cohen's (1960) Kappa.

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For the pretest, children were asked to:

1. draw a picture in response to the instruction "Do a drawing which tells me what you know about scientists and their work" (group class activity, directed by teachers).
2. explain the picture to the researcher (individual activity, coding form in Appendix E). This interview took about 15 minutes.
3. Respond to 15 epistemology statements by pointing to one of the expressive faces, varying from smiling to frowning (individual activity), while being videotaped. This process took about 10 minutes.

During the treatment period of three weeks, subjects experienced the classroom instruction as determined by the teachers and remote scientists. All of the instruction was designed by the collaborating teachers and PEARL scientists to fit National Science Education Standards. Multiple interactive and distance resources were used, such as computer mediated video conferencing, shareware software, email, and electronic field trips. I did not participate in curriculum design or implementation, but I did videotape the science class periods. When the lessons concluded, I proceeded with gathering posttest data.

For the post test a, the children:

Repeated steps 1, 2, and 3.

For the post test b, the children were:

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4. shown a picture drawn by the researcher (including all eight elements of the processes of science, see Appendix F) and interviewed using the same queries as were used for step 2.

In summary, in this study, epistemological beliefs were measured using a modification of Schommer's questionnaire. Scientific processes data were collected using Chamber's (1993) DAST method. The classroom teachers asked their students to make a drawing representative of their understanding of the processes of science. Then, various elements of the NSES K-4 standards on the processes of science "science as inquiry" were used to score students' drawings. Children were interviewed and video taped as they provided process explanations of their drawings and elaborated on their content.

Proposed Analysis

In this section proposed methods for analyzing quantitative data were specified (for an overview see Table 4, pp. 96-97). These original plans were partly adapted due to the actual results obtained.

To explore the underlying dimensions of children's epistemological beliefs, data from the epistemology questionnaire were to be used. To demonstrate whether Schommer's dimensions were replicated with the present sample, principal factoring extraction with orthogonal rotation was to be computed on the epistemology pre-test,

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Table 4

Epistemology and Processes of Science Study Overview

Research Question/Hypothesis	Data Source/ Instrumentation	Type of Analysis
1) What are the underlying dimensions of children's epistemological beliefs?	Children's responses to epistemology questionnaire.	Principal factoring extraction with orthogonal rotation computed on the pre test, using each item as a variable.
2) A positive relationship is expected between children's epistemologies and their understanding of the processes of science.	Processes of science scores, epistemology scores.	Set correlations used to examine relative contributions of epistemology to science understanding.

(table continues)

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Research Question/Hypothesis	Data Source/ Instrumentation	Type of Analysis
3) How do personal epistemologies and understanding of the processes of science change when children become exposed to scientists doing science?	Pre and posttest phase, for the epistemology questionnaire. Pre and posttest a phase, for the processes of science test.	Repeated measures (within subjects) ANOVA.

using every item as a variable. This method of factor analysis was the same type of analysis conducted by Schommer (1989) to derive her factors.

A positive relationship was expected between children's epistemologies and their processes of science. Set correlations were planned to examine the relative contributions of children's epistemological beliefs dimensions to children's understanding of the processes of science in the pre-tests. To answer the question "How do personal epistemologies and understanding of science change when children become exposed to scientists doing science?" both the pre and posttests of epistemology and processes of science were to be employed. A repeated measures (within-subjects) ANOVA was to be conducted. It was expected that children would become more knowledgeable about science processes, and that their gains would be influenced by their personal epistemologies.

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CHAPTER IV

RESULTS AND ANALYSIS

Introduction

In this chapter the results of my study are presented and analyzed. Descriptive statistics are provided for all the instruments. The reliability of the epistemology instrument is reported. The structural equation modeling program employed in this study and the results of a confirmatory factor analysis on Schommer's epistemology questionnaire data are described. Exploratory factor analyses and follow-up confirmatory factor analysis are described. In addition, individual epistemology items and instrument consistency are presented. Interrater agreement figures on the science instrument are reported.

The data gathered according to the methods described in Chapter III were analyzed using the planned procedures, and in addition, some further analysis is included. Science scores were analyzed using t-tests and regression. Participants informal reflections on the experience of science instruction via video teleconferencing are summarized.

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Epistemology

Descriptive Statistics.

This section begins with descriptive statistics for the epistemology instrument pretest and posttest. In Table 5 (p. 99) individual epistemological items are listed, along with their means and standard deviations. The lower the mean, the greater the epistemological sophistication (Schommer's term, 1989). For example, item 9 is a structure of knowledge item. The pretest mean of 3.18, indicates viewing knowledge as consisting of isolated facts. Inverted valance items 2, 3, 8, 11, 12, 16 and 18 (these items are indicated with an * in Table 5) were reversed for this table.

Table 5

Epistemology Pretest and Posttest Descriptive Statistics

	Epistemology Pretest		Epistemology Posttest	
Item	M	SD	M	SD
1. The best thing about science is that most problems have just one right answer.	2.09	1.15	2.13	1.25
2. If I can't understand something quickly, I keep trying.*	1.33	0.73	1.38	0.50
3. When I don't understand a new idea, it is best for me to figure it out on my own.*	1.91	0.87	2.36	2.95
4. I get confused when books have different information from what I already know.	2.59	1.05	1.00	0.95

(table continues)

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	Epistemology Pretest		Epistemology Posttest	
Item	M	SD	M	SD
5. An expert is someone who is born really smart.	2.00	1.23	2.00	1.41
6. If scientists try hard enough, they can find the truth to almost everything.	3.05	1.00	2.68	1.09
7. Students who do well learn quickly.	3.36	0.90	3.00	1.06
8. Getting ahead takes a lot of work.*	1.68	1.04	1.55	0.91
9. The most important part about being a good student is memorizing facts.	3.18	1.01	2.82	1.10
10. I believe what I read.	2.68	0.99	2.64	0.85
11. Truth never changes.*	2.36	1.05	2.32	1.13
12. Learning takes a long time.*	2.09	1.02	2.13	1.17
13. Really smart kids don't have to work hard to do well in school.	1.73	0.94	1.64	0.85
14. Kids who disagree with teachers are show-offs.	2.64	1.29	2.55	1.22
15. Scientists can get to the truth.	3.50	0.51	3.23	0.75
16. I try to use information from books and many other places.*	1.45	0.74	1.50	0.91
17. It is annoying to listen to people who can't make up their minds.	2.68	0.99	3.00	0.98
18. Everyone needs to learn how to learn.*	1.09	0.29	1.23	0.43

(table continues)

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19. If I try too hard to understand a problem, I just get confused.	2.95	0.99	3.09	1.11
20. Sometimes I just have to accept answers from a teacher even though they don't make sense to me.	3.14	0.99	2.86	1.17

In Table 6 (p. 102) the frequency distributions are reported for both the epistemology pretest and the posttest. The frequencies for Items 2, 3, 8, 11, 12, 16 and 18 have been inverted, because the items have a negative valence. Thus the scores in Table 6 are transformed and reported in the opposite direction in which they were originally scored.

Pretest and Posttest Stability.

In order to provide a measure of instrument stability, individual item correlations of pre and post epistemology results scores were computed. The correlations on individual items between the two administrations varied from a low of .03 to a high of .76, with a mean of .50. A nonparametric correlation (Kendall's tau-b, 1938) was employed because the four point Likert scale of the epistemology questionnaire imposed a limited range on the scores (see Table 7, p. 103) for a table of these correlations). The assumptions here are that the observations have been obtained in pairs (which they were in this study) and that the population's distributions are continuous. In this study the Likert epistemology scores represent an underlying continuous set of beliefs. The data are ranked and then the Pearson correlation coefficient is

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Table 6

Frequency Distribution for the Epistemology Pretest and Posttest

	Epistemology Pretest				Epistemology Posttest			
	Frequency				Frequency			
Item	1*	2**	3***	4****	1*	2**	3***	4****
1.	9	6	3	4	10	4	3	5
2.	17	4	0	0	14	8	0	0
3.	8	9	4	1	4	10	4	4
4.	3	9	4	6	2	4	9	7
5.	12	2	4	4	14	1	0	7
6.	3	1	10	8	5	2	10	5
7.	2	0	8	12	3	3	7	9
8.	13	6	0	3	14	6	0	2
9.	2	3	6	11	3	6	5	8
10.	3	6	8	5	2	7	10	3
11.	5	8	5	4	7	5	6	4
12.	7	9	3	3	9	5	4	4
13.	12	5	4	1	12	7	2	1
14.	7	2	5	8	6	5	4	7
15.	0	0	11	11	0	4	9	9
16.	14	7	0	4	16	2	3	1
17.	3	6	8	5	3	1	11	7
18.	20	2	0	0	17	5	0	0
19.	3	4	6	9	3	3	5	11
20.	2	3	7	10	4	4	5	9

Note (for Table 6): Frequency from a Likert scale: *1 = No, **2 = Sort of No, ***3 = Sort of Yes, and ****4 = Yes

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computed. Interpretation is the same as for Pearson's except that the relationship between ranks and not values is examined. In this study lower correlations may indicate a weak item or could be evidence of maturation or fluctuation in epistemological beliefs.

Table 7

Pretest-Posttest Stability for the Epistemology Instrument

	Kendall's tau-b Correlation Coefficient
Epistemology Items	Pretest with Posttest
1. The best thing about science is that most problems have just one right answer.	.586**
2. If I can't understand something quickly, I keep trying.	.491*
3. When I don't understand a new idea, it is best for me to figure it out on my own.	.322*
4. I get confused when books have different information from what I already know.	.462**
5. An expert is someone who is born really smart.	.476**
6. If scientists try hard enough, they can find the truth to almost everything.	.769**
7. Students who do well learn quickly.	.516**
8. Getting ahead takes a lot of work.	.703**
9. The most important part about being a good student is memorizing facts.	.591**
10. I believe what I read.	.477**

(table continues)

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Epistemology Items	Kendall's tau-b Correlation Coefficient Pretest with Posttest
11. Truth never changes.	.500**
12. Learning takes a long time.	.522**
13. Really smart kids don't have to work hard to do well in school.	.418*
14. Kids who disagree with teachers are show-offs.	.612**
15. Scientists can get to the truth.	.654**
16. I try to use information from books and many other places.	.390*
17. It is annoying to listen to people who can't make up their minds.	.031
18. Everyone needs to learn how to learn.	.583**
19. If I try too hard to understand a problem, I just get confused.	.502**
20. Sometimes I just have to accept answers from a teacher even though they don't make sense to me.	.395*
Mean Correlation	.500

Note. * Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Replication of Schommer's (1989) Epistemology Factors.

In Schommer's (1989) dissertation, 23 factors were originally generated, but she imposed an alternative criterion of five factors to test her model of

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epistemological beliefs. In order to determine if five orthogonal (uncorrelated) factors could be obtained from the data of this study, I replicated Schommer's (1989) initial process. Principal-Component analysis and Varimax rotation were applied to the epistemology questionnaire. The eigenvalues were set at a traditional value of 1.0, as in Schommer's (1989) factor analysis. This factor analysis duplicated Schommer's methods, but it did not replicate Schommer's (1989) factors using the chi-square for goodness-of-fit test ($X^2_{(190)}=443$, $p<.001$).

Although it is possible that the factors failed to replicate due to lack of construct validity, various characteristics of this study make it impossible to draw such a strong conclusion. The failure to replicate Schommer's (1989) factors could simply be due to the small sample size ($n=22$ students). In addition, Schommer's (1989) epistemology instrument was modified for this study. The entire instrument was shortened and individual items were simplified in order to accommodate the younger population under investigation.

Structural Equation Modeling.

The major assumption of factor analysis is that complex phenomena can be explained by underlying factors. Correlations between the variables are a result of sharing underlying dimensions (factors). EQS is the structural equation modeling program employed for doing the confirmatory factor analyses in this study (Bentler & Wu, 1995). In

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addition, SAS was employed to precisely duplicate Schommer's application of Principal-Components analysis and Varimax rotation. Analysis results were the same for both the EQS and the SAS programs. See Appendix G for a structural diagram of Schommer's (1989) initial five factor epistemology model. The five factors in this model are identified as Factor 1 (F1), Structure; Factor 2 (F2), Certainty; Factor 3 (F3), Source; Factor 4 (F4), Control; and Factor 5 (F5), Speed.

Standardized factor loadings show the relative contribution of each of the measured variables to the factor. The relationships in the path diagram of Appendix G can be illustrated by an example, thus a detailed description that begins with Epistemology, follows: the arrow between Epistemology (central oval) and Factor 3 (Source, in an oval) indicates a covariance of .85 between the two factors. The arrow from Factor 3 (Source) to the measured variable, EpistA10 (Epistemology pretest item #10, in a rectangle) represents a factor loading (or regression coefficient) of -0.24 and indicates the magnitude of the contribution to the latent variable Factor 3. The arrow from E13 to EpistaA10, with a value of 0.50, is an error variable that represents the variation in the measured variable that is not related to the latent variable. This is a residual in the regression equation. The structural equation model presented in Appendix G may be interpreted using the above example. This confirmatory factor analysis of these data using Schommer's

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five epistemological factors did not replicate Schommer's (1989) factors.

Exploratory Factor Analysis.

The items in the epistemology questionnaire did not cluster in the predicted manner, thus the confirmatory factor analysis was followed with an exploratory factor analysis. A good factor analysis is both simple and interpretable (Bentler & Wu, 1995). Six exploratory factor analyses were run on both the epistemology pretest and posttest, beginning with seven factors and continuing down to one. There was no replication of Schommer's five factors, nor was there a discernible pattern replicated from the pretest to the posttest. Thus it seemed reasonable to end the statistical exploration of epistemology at this point.

Science

Three measurements of children's understanding of the processes of science were conducted. The science pretest and posttest A use the same method to measure children's understanding of the elements of science (using children's drawings and interviews). Frequency distributions are provided in Table 8 (p. 108).

Posttest B was a variation on Posttest A as it also sought to measure children's understanding of science (using a picture as a stimulus and an interview). The purpose of administering posttest B was to provide an alternative measure of children's understanding of science to be used if posttest A did not yield usable results.

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Interrater Agreement.

Initially three raters (two Educational psychology graduate students and the author) trained using data from the pilot study. Four training sessions were conducted over a three week period. The criteria for the science categories

Table 8

Frequency Distribution for the Science Pretest and Posttest A

	Science Pretest Frequency		Science Posttest A Frequency	
Science Element	No*	Yes**	No	Yes
1. Ask a question...	10	12	9	13
2. Plan a simple investigation...	10	12	7	15
3. Employ simple equipment...	4	18	6	16
4. Use data to construct a reasonable explanation...	18	4	14	8
5. Technology	18	4	10	12
6. Communicate investigations and explanations.	8	14	8	14
7. People do science	0	22	0	22
8. Check each other's work...	20	2	18	4
Total score		88		104

Note: *No = Science element was not present in the drawing or in the interview. **Yes = Science element present in either the drawing or the interview.

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was refined, improving interrater reliability. The tests were scored by the three separate raters in a time-blind situation. Raters were unaware whether the tests were pre- or posttests. Interrater agreement was calculated for all three tests using Cohen's (1960) Kappa. The highest Kappas were those between one of the raters and this researcher. These Kappas are the ones reported in Tables 8, 9 and 10.

For the science pretest A the percentage of agreement ranged from 73% to 95%, with a mean of 83%. Kappas ranged from .46 to .95, with a mean of .70 (note that the level of agreement lowers the power of statistical tests run on these scores). Table 9 presents a chart of the individual scores.

For the science posttest B, the percentage of agreement ranged from 57% to 90%, with a mean agreement of 77%. Kappa ranged from .37 to .88, with a calculated mean of .60. The scores are reported in Table 10 (p. 111). The purpose of science posttest B was to provide a supplementary measure of the children's understanding of science. However, as interrater agreement was stronger for posttest A, posttest A will be used to measure children's understanding of science.

Science Scores.

To guard against researcher bias, the scores of the graduate student with the highest agreement were used to report pretest and posttest A results. The children achieved gain scores in the period between the processes of science

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Table 9

Interrater Agreement for Processes of Science Pretest and Posttest A

	Percentage of Agreement		Kappa	
Elements of Science	PretestA	PosttestA	PretestA	PosttestA
1) Ask	73%	91%	.46	.83
2) Plan	77%	68%	.56	.48
3) Employ	86%	82%	.77	.71
4) Use Data	73%	73%	.58	.41
5) Apply	82%	82%	.69	.64
6) Communicate	86%	91%	.72	.83
7) View	95%	100%	.95	1.00
8) Check	90%	91%	.87	.87
Means:	83%	85%	.70	.72

pre-test to the processes of science posttest. See Table 11 (p. 112) for a tabulation of the children's science pretest and posttest A total raw scores. Although these figures must be interpreted with caution due to the sample size of this exploratory study, the gain scores appear to indicate an increase in children's understandings of the processes of

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Table 10

Interrater Agreement for Processes of Science Posttest B

	Percentage of Agreement	Kappa
Elements of Science	Posttest B	Posttest B
1) Ask	86%	.72
2) Plan	66%	.37
3) Employ	81%	.77
4) Use Data	57%	.12
5) Apply	81%	.64
6) Communicate	90%	.87
7) View	90%	.88
8) Check	67%	.54
Means:	77%	.60

science during the period of this intervention. Out of 22 children 13 improved, 6 stayed the same, and 3 decreased in performance.

Analysis of Change in Science Scores.

A dependent samples *t*-test was conducted to determine if children's performance in the processes of science test changed significantly. In *t*-tests, populations are assumed to be normally distributed and have equal variances. The

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Table 11

Science Scores (Pre and Post)

Student	Pretest	Posttest A	Student	Pretest	Posttest A
1.	6	5	12.	3	5
2.	5	5	13.	4	4
3.	2	4	14.	5	7
4.	3	3	15.	4	4
5.	4	5	16.	3	4
6.	5	5	17.	3	5
7.	4	5	18.	5	4
8.	4	3	19.	3	3
9.	3	4	20.	5	6
10.	4	6	21.	5	7
11.	4	5	22.	4	5
			Totals	88	104

Shapiro Willks test of normality (p=.0088) indicated that normality was violated, but this has almost no practical consequences (Glass & Hopkins, 1996). In this study the groups are a bit small, but fortunately, t-tests are robust to assumption violation and significance was found. There is a significant increase in total science understanding scores, with a t-score =3.31, p =.003 with 21 degrees of freedom. In the science pretest the mean is 4, with a standard deviation of .98. In the science posttest the mean is 4.7, and the standard deviation is 1.12.

To examine children's performance in each of the eight elements of science, paired t-tests were calculated. Results were non-significant for all science elements except for element number 5. This element, Technology, ("Tools used by

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students and scientists and teachers to conduct inquiry and understand science", NSES, 1996) was significant, with a *t*-score =2.94, *p* =.007, with 21 degrees of freedom. Thus the significant results in the total science test appears to be due to the results of knowledge gains in this one element.

Regression Analysis.

The final analysis applied to the data in this study was a multiple linear regression. The assumptions for use of the regression were met by plotting the residuals, and noting that the variances were equal, centered around 0 and presented no pattern. Regression was used to investigate what proportion of the variance in the total science posttest scores may be explained by two variables: total score on the science pretest, and children's age. The regression model including these two independent variables has an R^2=.27, explaining 27% of the variance in the science posttest. The science pretest was a significant predictor of performance on the posttest (t=2.52, p=.02, with 19 degrees of freedom). It seems likely that this significance was due to the children's prior knowledge of science. It is important to note that age was not a significant predictor.

Participants Reflections on the Context of the Investigation.

Although the distance education (science instruction and the technology used to provide classroom access) was not the direct focus of this investigation, it did provide a distinctive context. As I reflect on the practical value of

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distance learning, I can discern that the experience clearly influenced all participants, offering possibilities and management difficulties peculiar to the medium. For example, even when, as a researcher, I was attempting to remain non-influential in the background, I would find myself nagging during science experiments "Please! Don't get the mike into the water!" The teachers had to manage an unfamiliar medium in addition to normal classroom management. The remote scientists provided science instruction even as they contended with a two-hour time change and novice computer-mediated video teleconferencing users.

The quantitative results indicated that the children learned about science from the process, but what did they think about their experience with distance learning? On the last day of school the teachers asked the children to reflect on their experience with Dr. Bob and to record their thoughts in their journals. In Appendix I, I have included copies of four children's' reflections (in their own handwriting, spelling and grammar) on what they learned their distance education experience. For example, one child reflects on gathering scientific evidence thusly: "I learned from Dr. Bob that scientists don't jump to cunclusians". Later the same child considers the need for tenacity, writing "I learned that if scientists are really on to something that they will not go off until they do it". Another child contemplates the need for replication in science, writing, "I learned that when scientist do an experiment they make hypotheses then try

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it once or maybe 20 time befor puting it in book & things they do that to make sure its true." The other two examples in Appendix I contain content information from the water lessons. Thus it seems that, from their own point of view, the most critical collaborators in this study, the children, found in this experience an opportunity to learn about science.

Summary of Results.

In this chapter the statistical analysis of both the epistemology questionnaire and the science instrument were reported. For the epistemology questionnaire descriptive statistics were provided, as well as pretest and posttest stability. Three attempts at factor analysis were made, including duplication of Schommer's process, EQS and exploratory factor analysis. Interrater agreement was reported three times for the science instrument. The science scores were analyzed using *t*-tests and regression analysis. Finally, some of the participants' subjective reactions to the experience were reported.

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CHAPTER V

SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Summary

The purpose of this study was to examine the relationship between the epistemology of young children and their understanding of science within the context of video teleconferencing with scientists. Two questions guided the study:

1. What is the relationship between children's epistemological beliefs and their understandings of the processes of science?
2. How does understanding of the processes of science change when children are exposed to scientists doing science?

Three instruments were administered, one to measure children's epistemology, the others to measure children's understanding of science. Science instruction was provided by remote scientists in collaboration with the classroom teachers.

The epistemology instrument was based on earlier epistemological work by Schommer (1989). Twenty items were included in an abbreviated instrument designed to

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replicate Schommer's five elements of epistemology. The criteria for selecting the items were the strength of the factor loading in Schommer's work and age appropriateness.

The science understanding instruments were based on the National Science Education Standards (1996). Eight elements of science were extracted from the NSES (1996). These elements were described in the NSES as concepts that should be acquired by children in this age group. Data on children's understanding of science were gathered using drawings about science and interviews. The NSES (1996) eight elements of science were used as a basis for quantifying children's understanding of science.

In order to carry out the study, a pre-existing elementary classroom was equipped with an ISDN line and computer mediated video teleconferencing technology. A total of twenty-four elementary-age school children participated in this study.

The data gathering was structured as pre and post intervention tests for both epistemology and science understanding. For the science pretest, the children drew pictures illustrating what they knew about science and scientists in response to a teacher initiated in-class activity. In addition, I interviewed the children separately, asking that they elaborate on their drawings in a semi-structured interview. To measure epistemology, I individually administered the epistemology questionnaire.

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A four week program of collaborative science instruction via video teleconferencing followed. Although I had no control over the content of the science instruction, it is important to note that the classroom is located in Colorado, and is thus required by law to meet or exceed Colorado science standards each year (Colorado HB95-1313, 1995).

Post-intervention data were gathered in the same process as was described in the pretest. Finally, a supplementary measure of the children's understanding of science was taken. Children were provided an illustration of the elements of science and asked to describe the drawing.

Summary of Findings

Research Question One.

The confirmatory factor analysis failed to replicate Schommer's (1989) five epistemological factors. Thus I attempted to investigate the underlying dimensions of children's epistemological beliefs by using exploratory factor analysis. However, no pattern emerged from the exploratory factor analysis. Because I was unable to detect underlying dimensions in the epistemological data, I could not proceed with analysis of relationships between epistemology and science processes.

Research Question Two.

The dependent samples *t*-test indicated that the children's performance in the processes of science increased significantly from science pretest to science posttest. *T*-tests showed that the performance increase was the result of

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one particular element, that of technology. A regression analysis indicated that the science pretest explained 27% of the variance in the science posttest.

Discussion And Recommendations for Future Research

Science.

The strongest finding in this study is that children learned about science from this brief intervention. In this study I measured children's understanding of science using an instrument based on elements of science extracted from the National Science Education Standards. The results indicated the children in this study already knew one of the elements, remained naive to another and responded strongly to instruction on one. The children already knew that people do science, thus they understood the concept of "nature of science as a human endeavor" (NSES, p. 170, 1996). The children did not know at the beginning of the study that scientists check each other's work, and they remained naive about this feature at the end of the study. Thus the NSES concept that "scientists review and ask questions about the results of other scientists work" (p. 123, 1996) appeared to elude the children in this study. The children did appear to learn about the role of educational technology in science, demonstrating a new understanding of "tools used by students and teachers to conduct inquiry and understand science" (NSES, p. 24, 1996).

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However, as there was no control group in this study, the gains reported in science understanding must be interpreted with caution. Exactly which element of the intervention was responsible for the gains remains unclear. For example, normal class science instruction continued, and the children did mature over the three week period. Results might have been due to the science instruction provided in the intervention, or due to a reaction to the video teleconferencing medium.

Another interesting result of this was that age was not related to science understanding. This was particularly interesting in a classroom that included first, second, and third grade students. Thus children with age differences as great as three years seemed to be understanding science based more on their educational experiences than on their chronological age. This raises questions concerning the concept of stage development, frequently discussed in education as 'learning readiness' Are children limited in what they learn about science primarily by the curriculum they are offered, rather then by a developmental stage?

One issue that became clear during the development of the science instrument is that it is difficult to operationalize the National Science Education Standards into a quantifiable measure. Yet, as a society, we have legislated standards and expect classroom teachers both to implement them instructionally and then measure their students' achievements. But are these standards

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developmentally achievable? Is there a curriculum effective in achieving the science standards? These questions remain to be answered.

Epistemology.

This study produced only glimmers of insight into children's epistemological beliefs. Children were able to understand the epistemological questionnaire and readily chose a position on the Likert scale, indicating that the instrument was practical for application with this age group. The most obvious recommendation for future research in children's epistemology is to increase sample size and re-administer the epistemology instrument. It would be helpful to do so at intervals, so that mapping children's development of epistemological beliefs could begin.

Once the identification and measurement of children's epistemological beliefs has been achieved the next question is what influence they might have on learning. If epistemological beliefs do impact children's learning can anything be done to impact the development of these beliefs? If children's epistemological beliefs are in the form of implicit knowledge, then they may be resistant to change because students are not even consciously aware of their beliefs (Schraw & Mosham, 1995). Thus attempting to influence epistemological beliefs may present a challenge to the classroom teacher. How could a teacher attempt to influence epistemological beliefs in the classroom? A currently suggested pedagogical approach to influencing

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epistemological beliefs "is to provide classroom experiences that lead students to discover that knowledge must necessarily be a dynamic, rather than static, entity and to realize that successful learning sometimes occurs only through effort and persistence" (Ormrod, in press, p. 607). Are epistemological beliefs ripe for pedagogical intervention at any specific age? Are there ethical issues concerning attempting to influence epistemological beliefs?

Context.

The context of this study, which included a collaborative instructional effort between classroom teachers, students and remote scientists using computer mediated video teleconferencing indicated that using this advanced communications technology as a classroom resource is feasible within the regular curriculum. The major reason the video teleconferencing is now practical is because the cost of using ISDN lines has plummeted, as has that of computers, making the hardware available (Morgan, 1994). Thus, video teleconferencing is now just another classroom resource, and the question remaining is how best to apply this medium.

In the present study the children and teachers experienced an unfamiliar medium, computer-mediated video teleconferencing. However, the computer-mediated video teleconferencing entered the classroom through a 25-inch television screen, a familiar medium, most frequently associated with entertainment. It is assumed that some adjustment to this medium's symbol systems resulted, but the

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examination of these adjustments was beyond the scope of this study.

The collaboration of teachers, scientists and students in this study raised many questions. For example: In collaborative instruction, what are the respective roles of the remote and local teacher? What is the function of an expert in the classroom? What are the training issues in achieving efficacy of instruction? Who develops the curricula? What domains lend themselves best to this medium? What types of remote resources can be accessed with video teleconferencing field trips (language study, museums, and experts)? What age groups can use this method most beneficially? Are there longitudinal effects?

In concluding this long list of questions pointing toward future research, I find myself turning to the role of affect in learning and instruction. The medium of video teleconferencing adds a layer of coping skills that must be used to compensate for the distance. Participants (teachers, students and scientists) must value distance learning in order to engage in the processes required. As Vygotsky (1962) noted, learning is social in nature, a product of interactions among student and educator. The implementation of this study involved many social interactions among the educational psychologist, the students, the teachers and the scientists. Was it pedagogically valuable? In the words of one of the classroom teachers, it was most valuable "... when we found ourselves (teachers included) doing things and

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[achieving] understandings which would not have happened without Bob's [the scientist's] expertise" (T. Beaver, personal communication, May 23, 1996).

This exploratory field study has raised far more questions than it has answered in the areas of children's epistemological beliefs, and in the application of advanced communications technology in the classroom. Issues have been raised concerning children's understanding of science, the use of standards to measure children's competencies in the domain of science and the need for models for collaborative efforts to improve science instruction.

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APPENDIX A

Relationship Between Epistemology and Science

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Predictions on Associations Between

Science Processes and Epistemological Beliefs

Dimensions of Epistemology — Elements of the Processes of Science

	Ask	Plan	Employ	Use data	Apply	Communicate	View	Check
source	x			x			x	x
certainty	x				x			x
structure		x	x	x		x		
control	x	x					x	
speed		x		x				

APPENDIX B

Modification of Schommer's Epistemology Questionnaire Categories

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Schommer's Epistemological Questionnaire Categories
(Modified for 8-10 year old Children)
By Janie Mefford Shaklee

Category/ Valance	Item #	Epistemological Item
		<u>Source of Knowledge</u>
-	3.	When I don't understand a new idea, it is best to figure it out on my own.
+	10.	I can believe what I read.
+	14.	Kids who disagree with teachers are show-offs.
+	20.	Sometimes I just have to accept answers from a teacher even if they don't make sense to me.
		<u>Certainty of Knowledge</u>
+	6.	If scientists try hard enough, they can find the truth to almost everything.
+	15.	Scientists can get to the truth.
-	11.	Truth never changes.
+	17.	It is annoying to listen to people who can't make up their minds.
		<u>Structure of Knowledge</u>
+	1.	The best thing about science is that most problems have one right answer.
+	4.	I get confused when books have different information from what I already know.
+	9.	The most important part about being a good student is memorizing the facts.
-	16.	I try to use information from books and many other places.

(Appendix continues)

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Control of Knowledge Acquisition

+ 5. An expert is someone who is born really smart.
+ 13. Really smart students don't have to work hard to do well in school.
- 8. Getting ahead takes a lot of work.
- 18. Everyone needs to learn how to learn.

Speed of Knowledge Acquisition

- 2. If I can't understand something quickly, I keep trying.
+ 7. Students who do well learn quickly.
- 12. Learning takes a long time.
+ 19. If I try too hard to understand a problem, I just get confused.

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APPENDIX C

Modification of Schommer's Epistemological Questionnaire

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Modification of Schommer's Epistemological Questionnaire

(Revised for 8-10 year old children)

__Instructions:__ Read items to child. After each item, have child point to face which best shows their opinion. Circle the response on the score sheet.

Use items A. and B. for practice, prompt if needed.

A. Are cats green?

(Prompt: "Which card shows how you feel about this?")

B. Is it a nice day?

1. The best thing about science is that most problems have one right answer.
1 2 3 4

2. If I can't understand something quickly, I keep trying.
1 2 3 4

3. When I don't understand a new idea, it is best to figure it out on my own.
1 2 3 4

4. I get confused when books have different information from what I already know.
1 2 3 4

5. An expert is someone who is born really smart.
1 2 3 4

6. If scientists try hard enough, they can find the truth to almost everything.
1 2 3 4

7. Students who do well learn quickly.
1 2 3 4

8. Getting ahead takes a lot of work.
1 2 3 4

9. The most important part about being a good student is memorizing the facts.
1 2 3 4

ID#______________

10. I can believe what I read.
1 2 3 4

11. Truth never changes.
1 2 3 4

12. Learning takes a long time.
1 2 3 4

13. Really smart students don't have to work hard to do well in school.
1 2 3 4

14. Kids who disagree with teachers are show-offs.
1 2 3 4

15. Scientists can get to the truth.
1 2 3 4

16. I try to use information from books and many other places.
1 2 3 4

17. It is annoying to listen to people who can't make up their minds.
1 2 3 4

18. Everyone needs to learn how to learn.
1 2 3 4

19. If I try too hard to understand a problem, I just get confused.
1 2 3 4

20. Sometimes I just have to accept answers from a teacher even if they don't make sense to me.
1 2 3 4

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APPENDIX D

Graphic Likert Scale

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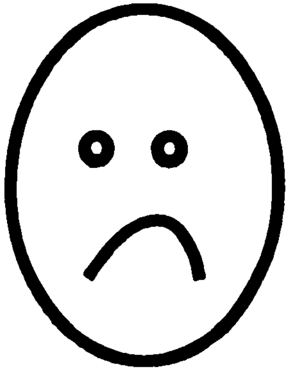
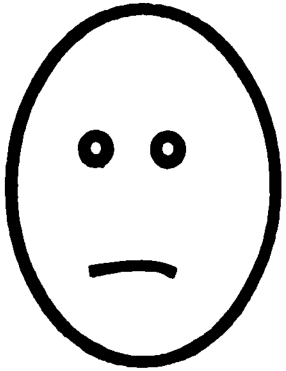
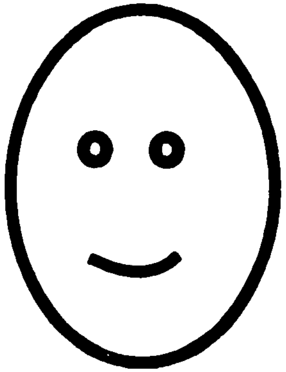


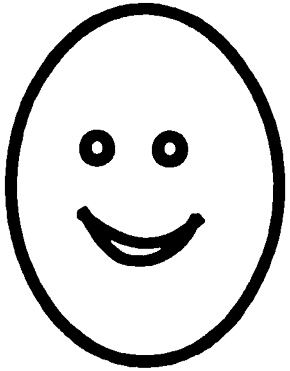
1. No



2. Sort
of no.



3. Sort
of yes.



4. Yes

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APPENDIX E

Understandings about Scientific Processes

Scoring Criteria/Score Sheet

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Examples of Science Raw Data that was Scored Positive by Rater

Element of Science	Example of Element Appearing in Child's Drawing or Interview
1. Ask a question.	In the drawing: A large question mark appears.
2. Plan a simple investigation.	In the drawing: Two bubbling test tubes were taken as evidence of an experiment in action, evidence of a plan.
3. Employ simple equipment.	In the drawing: A magnifying glass.
4. Use data to construct a reasonable explanation.	In the drawing: A bar chart.
5. Apply technology.	In the drawing: A computer.
6. Communicate investigations and explanations.	In the interview: "...by the scientists showing them what he did so they will believe him."
7. View science as a human task.	In the drawing: A human being is depicted in the drawing.
8. Check each other's work.	In the interview: By having someone go up and see if it is really true or not.

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Understandings about Scientific Processes Scoring Criteria/Score Sheet: For Drawing & Interview

Scores	Query	Abilities for Scientific Inquiry: Detailed Description
_	1. Ask a question... "What's happening?"	"Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world."
_	2. Plan a simple investigation... "How is this being done?"	"Scientists use different types of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting)."
_	3. Employ simple equipment... "What's being used?"	"Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain by using only their senses."
_	4. Use data to construct a reasonable explanation... "Why is that?"	"Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations."
_	5. Technology "What is this? What is it used for?"	"Tools used by students and teachers to conduct inquiry and understand science.
_	6. Communicate investigations and explanations... "Now, what happens with what was learned?"	"Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
_	7. People do science "Who did this?" M/F	"Nature of science as a human endeavor"
_	8. Check each others work... "How do they know this is so?"	"Scientists review and ask questions about the results of other scientists work."

Total ____________________

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APPENDIX F

Researcher's Scientific Processes Drawing

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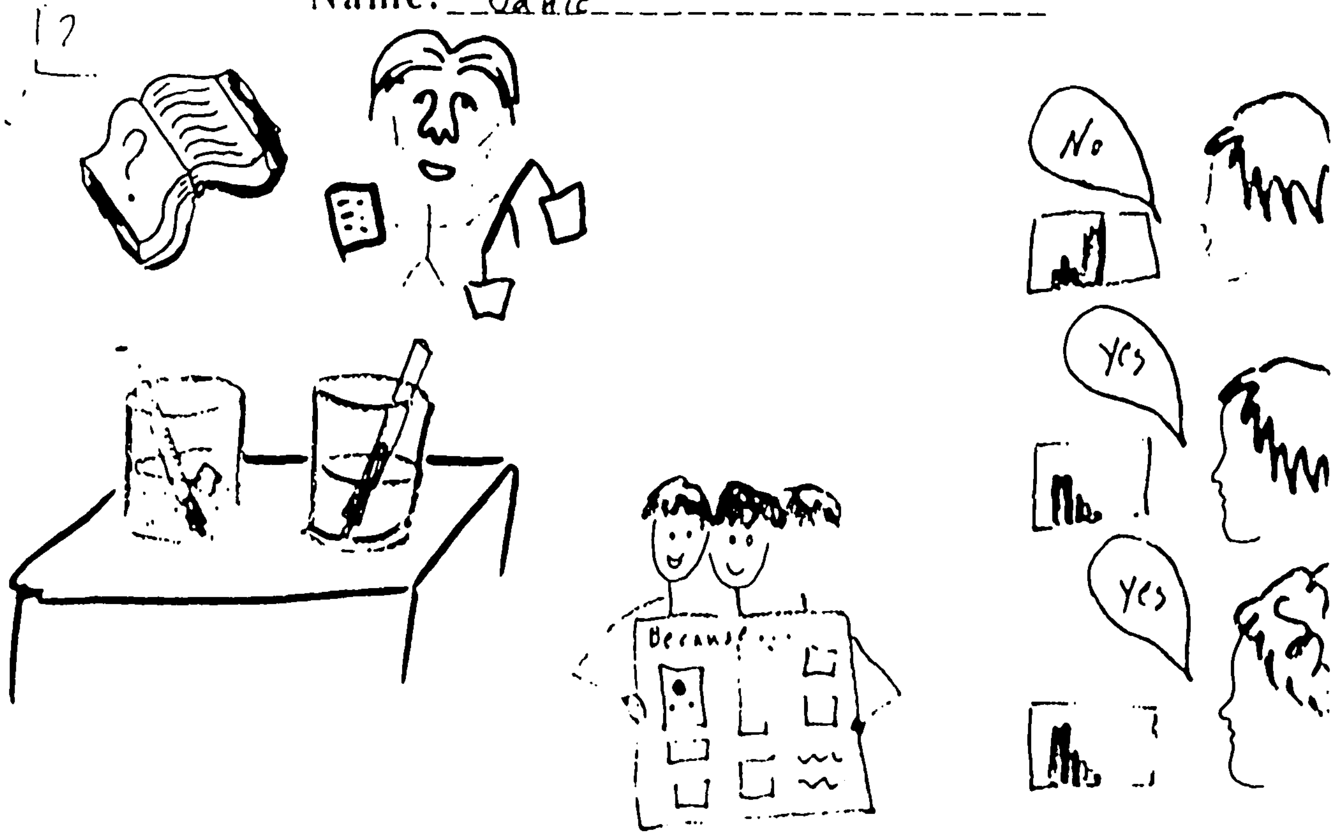
What I know about scientists and their work.

Name: Janie



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APPENDIX G

EQS Diagram of Schommer's Five Factors

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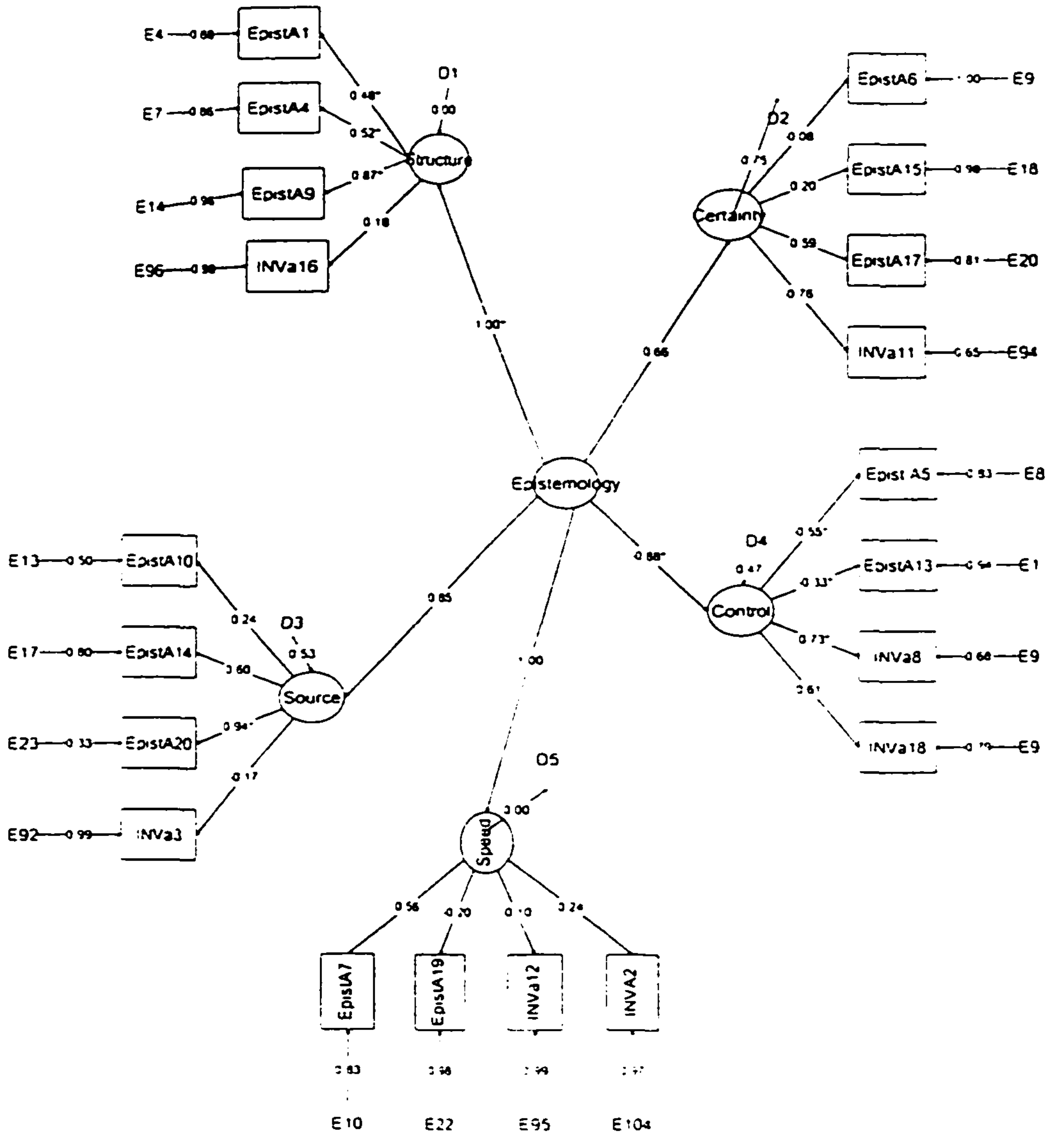

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APPENDIX H

Child's Science Posttest Drawing

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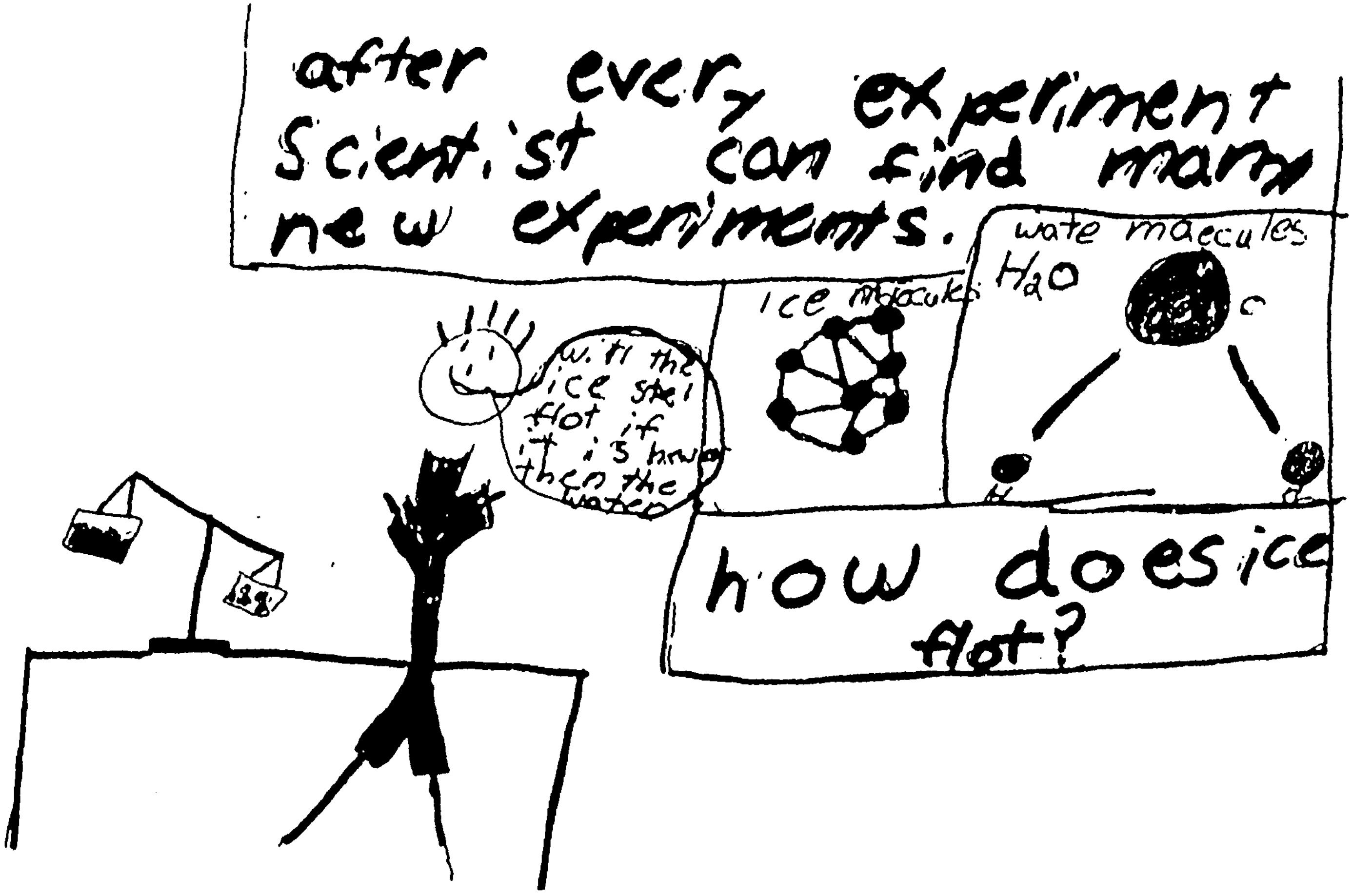

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APPENDIX I

Children's Reflections

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5-23-96

I learned from Dr. BoB that scientists don't jump to conclusions they do experments. I also learned that you can turn ice into water and the turn the water to steam and back to water again. I wish that I was at Nasa with the T.L.C but I could not cause my Grandma died but that is still important to me. I also learned that Ice floats in water, because of its shape and because of its temperature cause I did an experment on its temperature and cold water goes up and hot goes down. I hope we see him again. I learned that if scientists are really on to some-thing that they will not go off it until they do it. I bet are Technology will be high and we will come [illegible]

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a cure for cancer and
that would be really
good [illegible]
[illegible]

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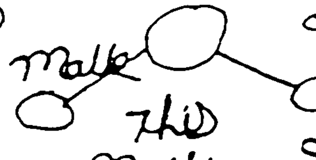
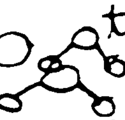
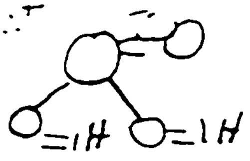
Meets With Dr. Bob

I learned that

water Mallacls look like this  and when they malle the look like this  and they keep Malling around to other mallacls and when it is frozin it looks like this  and they Malles very slow and when it started to heat up they malle faster and faster and they run all adder and when it starts boiling they run even faster and I found out that H_2O stands for ↙ and I learned that



water ellaprats and Malles a little and rains and it goes on and on

$1H + 1H = H_2$

and $H_2 + O = H_2O$

may 231996 !

I learned that when scientist do an experiment they make a hypotheses & then try it once or mabey 20 time befor puting it in book & things they do that to make sure its true. I also learn that a molecule is made of hydrogen & oxygen I was excited to meet Some one the Computer and actely Geting to meet with them every time We meet I all ways felt Like a scientist for that while that We talked he taught us what Lot of big Words & Stuf & I learned

So much

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I LRND FROM DOCTR BOB
WATER MALKUWLS MOVE FASTR
IN LIKWED FORM AND ICE
HAS HOLS IN IT THATS WHY IT
IKSPANS AND WE LRND
A WAY TO TELL IF WATER
IS HOT STAP ONE PUT
A BLACK PES OF PAPR OVER
THE WATER STEAP TWO
WATE FOR 15 OR30 SAKINTS
AND LYFT THE PAPR UP
IF IT IS A LITEL WEAT
THE WATER IS HOT AND HE
WAS WARY NISE TO US TOO AND
AND THE SAP OF ICE MALCULS
IS SOT OF LIKE A HOSE

AND THE SAP OF ICE MALCULS
IS SOT OF LIKE A HOSE

SHAR AND RAIN IS COSD BY DAKS IDS
AND WEN THE CLOWD IS
FAUL OF WATER IT CUMS BAK
DOWN IN RAIN

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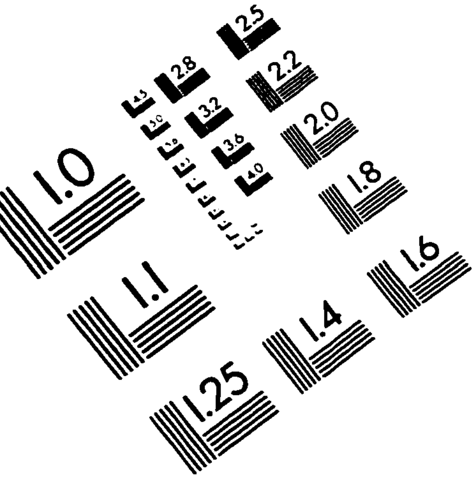

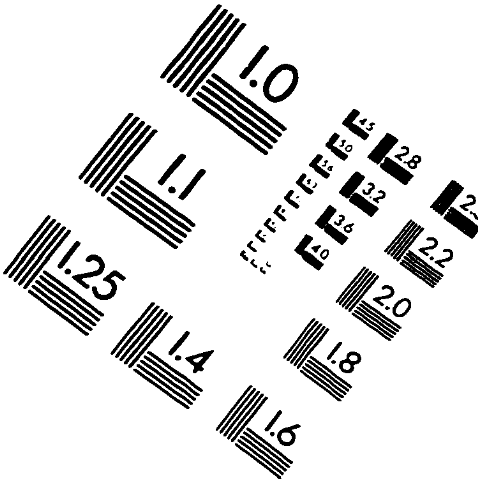

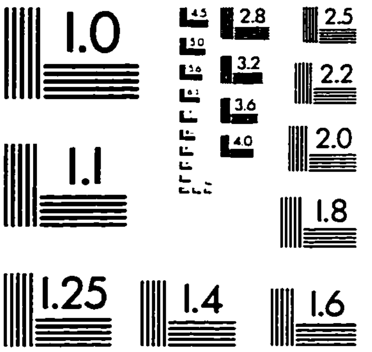

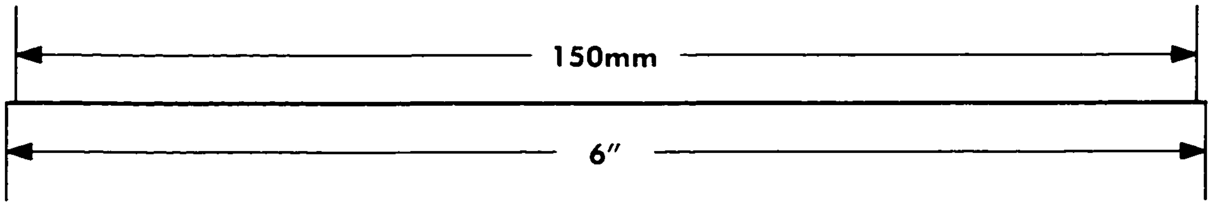

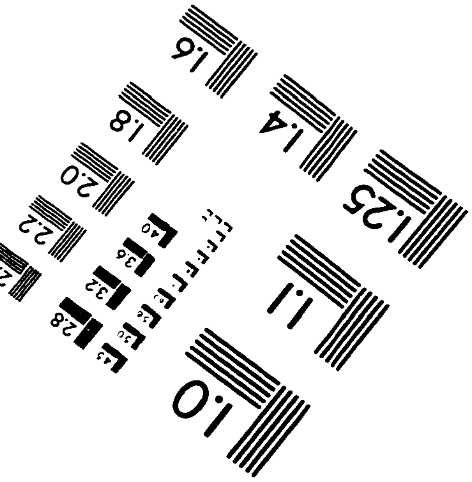

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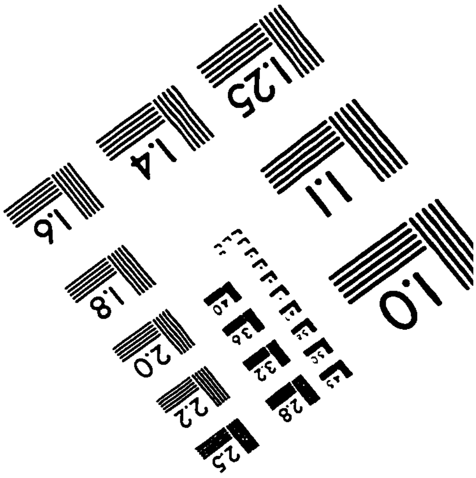

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