Supporting student learning through scientific inquiry

Allison J. Barness
University of Northern Iowa

Supporting student learning through scientific inquiry

Abstract

The purpose of this review is to identify the kind(s) of early childhood science instruction and learning environment that best supports student learning in science. The research examined focused on teacher actions and pedagogy, which also addressed student learning as outcome of the different studies. In addition, the research analyzed both the physical and the psychological environments, as both are important aspects which support student learning in science. A variety of sources were used and synthesized to provide the reader with informational data and recommendations.

Supporting Student Learning Through Scientific Inquiry

A Graduate Review

Submitted to the

Division of Early Childhood Education

Department of Curriculum and Instruction

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts in Education

UNIVERSITY OF NORTHERN IOWA

By

Allison J. Barness

June 6, 2011

This Review by: Allison J. Barness

Titled: Supporting Student Learning Through Scientific Inquiry

has been approved as meeting the research requirement for the

Degree of Masters of Arts in Education.

6-7-11
Date Approved

Graduate Faculty Reader

Jill Uhlenberg

6-8-11
Date Approved

Graduate Faculty Reader

Jill Uhlenberg

6-8-11
Date Approved

Head, Department of Curriculum and Instruction

Abstract

The purpose of this review is to identify the kind(s) of early childhood science instruction and learning environment that best supports student learning in science. The research examined focused on teacher actions and pedagogy, which also addressed student learning as outcome of the different studies. In addition, the research analyzed both the physical and the psychological environments, as both are important aspects which support student learning in science. A variety of sources were used and synthesized to provide the reader with informational data and recommendations.

Table of Contents

Chapter I

Introduction

Background

This review is designed to explore student learning through a scientific inquiry approach in the early childhood classroom. Following a review of salient research, the final chapter of this paper will present recommendations for teachers, administrators and future researchers to provide adequate professional development for educators, support teachers in their quest to teach science inquiry, and conduct more research in the area of inquiry at the early childhood level.

Throughout the years many educational philosophers and theorists have attempted to influence and develop new ideas and hypothesize about how children learn best. "Teaching is the process of education that is guided by educational values, personal needs, and by a variety of beliefs or generalizations that the teacher holds to be true" (Eisner, 1994, p. 154). As educators it is our job to create a learning environment that supports intellectual growth. Other theorists and philosophers have also contributed to the idea of teaching as inquiry.

John Dewey (1859-1952) defined inquiry as "the controlled or directed transformation of an indeterminate situation into one that is determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole" (cited in Hickman, 1997, p. 1). As complicated as this definition seems, it really is quite simple. For students, this means they learn side by side along with the teacher in an environment that challenges and supports classroom discovery rather than sitting at a desk restating non-related facts and skills. This gives students real and genuine learning opportunities and allows the teacher to be engaged in the same learning goals as the students (Inquiry-based education, 1997).

As their teachers we need to create supportive learning environments that guide and facilitate scientific inquiry so that children develop a natural love for learning. Inquiry works for many learning environments and situations, and can help students to create an understanding for their learning rather than simply memorize information and facts. Teaching with a scientific inquiry approach allows students to learn science with real-life experience and develop a deep understanding for the content. "Young children are naturally curious. The desire to question, hypothesize, explore, and investigate is part of their very being" (Bosse, Jacobs, & Anderson, 2009, p. 10). When teachers focus on the process of science, this allows them to be flexible in their instruction to meet the needs of all their students. At the same time, students are building on their process skills which help to form the core of inquiry-based learning (Funk, Fiel, Okey, Jaus, & Sprague, 1985). It is important to remember, however, that just because students are investigating information through hands-on learning, it doesn't mean they are learning with an inquiry-based approach. An inquiry-based teacher will facilitate and guide his/her students while allowing them to explore and make meaningful connections. Klien, Hammrich, Bloom, and Ragins' (2000) research discussed ". . . a model that fosters science learning through a systematic approach to understanding language at increasingly higher levels of abstraction by using questioning skills..." (Klien, Hammrich, Bloom, & Ragins, 2000, p. 1).

A scientific inquiry classroom combines the use of hands-on investigations along with thought-out questions that probe and guide students to further discovery. The teacher, as the guide, creates an environment and opportunities where students can wonder, reflect, question, explore, investigate, and formulate their own ideas and theories (Chalufour & Worth, 2003). Scientific inquiry is the process of learning and teaching that can take place within the science classroom. I believe that teaching science content does not mean you are teaching with an inquiry approach nor does teaching with inquiry necessarily mean you are teaching science. I also believe that science is not the only content area that is appropriate for inquiry learning. Bosse et al. explained that children carry out exploration of materials and inquiry in their everyday activities. They continued by elaborating how adults can foster this curiosity through science-inquiry activities in a rich and safe environment. Educators can purposefully plan lessons in which students are asking questions and seeking answers. Through this exploration students will develop higher order thinking skills through new ideas and their discussion with teachers and peers (Bosse et al., 2009).

Rationale

Science is everywhere, but typically not in our current US classrooms. "The No Child Left Behind Act has created problems for science educators by pressuring school administrators to focus on the subjects that will be tested in school evaluations," stated National Science Teachers Association Executive Director Gerald Wheeler (Price, 2008, p. 31). Due to our focus on standardized tests from the pressure of No Child Left Behind many of our schools have dropped the teaching of science or have replaced it with disconnected facts instead of learning through big ideas or questions that promote critical reasoning and problem-solving skills (Olsen & Loucks-Horsley, 2000). It is important for all students to be able to investigate, discover, and uncover learning in an environment that is authentic and provides opportunities for further questions and learning. "We have elementary teachers coming to us and saying: The principal's saying stop teaching science — get to reading and math," reported National Science Teachers Association Executive Director Gerald Wheeler (Price, 2008, p. 31).

It is important for teachers to see how to create an environment that best supports science through an inquiry approach and child investigations while meeting standards and requirements for student learning within the science classroom. Tu expressed that science is a way children begin to understand how our world works. Teachers can use this process to promote scientific thinking. Through this process children need a supportive environment so they can experiment and begin to discover for themselves (Tu, 2006). The environment in which the students are placed needs to support not only their physical needs but also their psychological needs. It is important for educators to be thinking of the whole child and how we can best support his or her learning needs. The reason for this review is to uncover how teachers can best support students in the area of science through their instruction and environment.

Purpose of Review

The purpose of this literature review is to examine research to determine what kind(s) of science learning instruction and environment can best meet the needs of our early childhood learners. Throughout this paper you will find a variety of examples that support inquiry-based teaching and demonstrate the importance of science inquiry in the early childhood classroom. Young children have a natural curiosity; when students begin to investigate and discover about the world around them their first encounter with science has taken place (Tu, 2006). It is important for students to uncover their interest for learning. Through investigations and with supportive adult guidance, young children can engage in complex discussions and discoveries using prediction and observations (Peterson & French, 2008).

Importance of Review

It is important not only to determine what the environment should be like to help guide and facilitate science learning, but also to inform teachers of the value of inquiry-based learning within their curriculum. The purpose of this review is to help educators see the value of teaching science in the early childhood classroom. As you will see there has not been a lot research in the area of science inquiry conducted at the early childhood level. My goal is to provide concrete evidence to support inquiry-based learning and an environment that supports all learners, as well as to identify where further research can be conducted.

Students who participate in inquiry-based science learn how to make meaning through investigations and through their own questioning. These skills prove to be valuable in the later grades in all curricular areas. Tu (2006) found that in order for students to begin scientific thinking they need a supportive environment that upholds their quest for new learning and discoveries. It is essential for schools to support and promote scientific inquiry by providing students with a rich learning environment that encourages students' self discovery.

It is important for schools to recognize our ever changing societal needs and the needs of our children. Our schools need to prepare our students for a world yet unknown, because students need to be able to adapt, change, question and synthesize about the world in which they live. Olsen and Loucks-Horsley, in their review of studies examining inquiry-based teaching with older children, found the following positive outcomes: "...conceptual understanding, critical thinking, inquiry abilities and physics understanding, and positive attitudes toward science" (Olsen & Loucks-Horsley, 2000, p. 125). They continued to elaborate on how, in these studies, which were usually of underrepresented and underserved populations, inquiry-based teaching improved students' ways of writing, thinking, and talking (Olsen & Loucks-Horsley, 2000).

Inquiry-based teaching becomes much more than just teaching science. It becomes a way of teaching and learning everything; all integrated into one. Students can learn how to read while investigating worms or how to count by tallying the number of eggs that have hatched. Science as inquiry can provide the context to learning literacy and math skills that can create an atmosphere of self-motivated and interested learners within the classroom.

Terminology

For the purposes of this paper, I am defining the following terms:

Constructivism - "Theory of creating one's own understanding of the world through interaction with materials, experiences, and people" (Gestwicki, 2007, p. 456).

Curriculum - "Methods and content to be taught" (Gestwicki, 2007, p. 456).

Curiosity - "Interest leading to inquiry" (Merriam-Webster Online Dictionary, 2010).

Early Childhood Education - Teaching any child between age 0 and age 8 (NAEYC, 2011).

Elementary Education - Teaching any child between kindergarten and sixth grade.

Epistemology - "The study or a theory of the nature and grounds of knowledge especially with reference to its limits and validity" (Merriam-Webster Online Dictionary, 2010).

Explore - "To investigate, study, or analyze" (Merriam-Webster Online Dictionary, 2010).

Inquiry -"A seeking or request for truth, information, or knowledge" (Dictionary.com, 2010).

Investigation -"To observe or study by close examination and systematic inquiry" (Merriam-Webster Online Dictionary, 2010).

Learning Environment - a place where we learn from selected materials, peers, and interactions for the purpose of what the preparer wants us to learn.

Nature of Science- "Values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavor" (Schwartz, Lederman, & Crawford, 2004, p. 611).

Scaffolding - "The process of linking what a child knows or can do with new information or skills the child is ready to acquire. Another individual is likely instrumental in this process" (Gestwicki, 2007, p. 455).

Scientific Inquiry - "Describes a range of philosophical, curricular, and pedagogical approaches to teaching. Its core premises include the requirement that learning should be based around students' questions" (Harvey & Daniels, 2009, p. 55).

Research Questions

Many early childhood teaching professionals believe that without a science background, teaching science is difficult, if not impossible for them to do. This may be because they lack confidence because they do not have a firm background in science content, or they struggle with the unpredictability that science sometimes brings. Using a science-inquiry approach, teachers do not need to know everything, nor do they need to have all the answers for the students. However, it is important that teachers have a basic understanding of content, along with the willingness and disposition to learn more, guided by the children's interests. The key to inquiry-based teaching and learning is to be a lifelong learner and demonstrate initiative to ask questions and find answers. Demonstrating this can be difficult for some teachers due to the nature of our school systems and the restraints on teachers and instruction. It is also difficult because the inquiry approach requires teacher to give up some power to the students. For teachers who consider themselves to be lifelong learners, someone who learns along with the students and shows them how to ask questions and seek answers, inquiry is more natural. The National Science Teachers Association (NSTA) (2007) also highlights the importance for inquiry in the classroom, by elaborating how inquiry-based investigations should be at every level and be at the core of every science program. It should be *how* we teach science and integrate it into each lesson and concept.

The goal of this review is to provide educators with researched-based information that will provide them with the foundation, resources, and confidence to begin teaching with inquiry in the classroom. For this reason, I chose to focus my review on the following questions:

1. What kind(s) of early childhood science instruction best supports student learning in science; and

2. What kind(s) of early childhood learning environment best supports student learning in science?

Chapter II

Methodology

The methodology I chose to use to locate, select, and analyze the research is provided in this chapter. I will explicitly demonstrate how sources were organized and reviewed to provide concrete evidence to support my final conclusions. Finding current research and information about scientific inquiry at the early childhood level has proven to be difficult. Much of the research about scientific inquiry that has been conducted has been done at the higher grade levels of school. This fact has forced me to modify my methodology somewhat.

Method to Locate Sources

At the beginning of my search I focused mostly on early childhood physical science and science inquiry. I quickly realized this was much too narrow and broadened my search to include all science inquiry at the early childhood level. Through further investigations I concluded to look for what kind of science learning instruction best meets the needs of students. Although some of the research I found was generalized to all children, not just early childhood, I was able to gather high quality information that could be applied to young children.

While searching for quality research and articles I used a variety of tools and methods to locate information. I found many journal and research articles using the ERIC search engine on the Rod Library homepage through the University of Northern Iowa. I also located other sources through Google Scholar and the *Early Childhood Research and Practice* site. I utilized the reference lists of many of the research articles I reviewed to guide me in my search for more information.

Finding quality pieces of research to support my question about the environment proved to be difficult. I chose to include essays that I found valuable to help refine my conclusions. Although they are not always research based, they do help to provide some insight on the best environments that support student learning.

Some of the key words I used when exploring information included: *science inquiry, science investigation, early childhood science practice, scientific inquiry at the early childhood level, inquiry vs. direct instruction, direct instruction,* and *science teaching at the early childhood level.* I also utilized many books and texts which served as guides in locating quality information and research, as well as providing me with a deeper understanding of the content. I have located these through library searches, colleague recommendations, and sources from the research articles I selected.

Method to Select Sources

While selecting quality sources I began focusing my search for primary and early childhood classrooms where teachers teach using scientific inquiry. I also looked at articles and research written about well known researchers of the past such as Jean Piaget, John Dewey, and Lev Vygotosky. My goal in doing this was to reflect on what has been viewed as best practice in the distant past and what is viewed as best practice today. The main articles I selected had been primarily from 2000-2011; however there were some articles that dated back to 1985 and because of the importance of these articles to my knowledge and understanding of the field, I have chosen to include them.

Procedure to Analyze Sources

The procedure I used to analyze the sources was an annotated bibliography. As I read and reflected on the sources, I took notes and recorded quality quotes which helped to summarize the main ideas of each article.

I also completed a chart that compared and contrasted the main ideas and points of articles and the research. The components I recorded were the authors' names, research questions, participants, procedures, measures used, analyses, results, and finally the authors' conclusions. This method helped me to compare and contrast the articles and research in an organized and systematic way. Some overarching themes in the articles I chose were *science teaching instruction*, *classroom environment*, and *student learning outcomes*. I used these themes to organize my research and arrange my paper to later draw my conclusions on what kind of science instruction and environment best meets the needs of our students.

Criteria to Include Literature

While gathering current research and articles I was looking for information about science teaching that could be applied to young children. I wanted to include information about elementary and early childhood science education.

The research I found to be most useful has been action research done with young children, focusing mostly on preschool through grade 2. This type of research gave clear examples and real situations where students were asking questions and guided in finding their own answers. The research I found also mainly focused on the classroom environment as a community of learners and the teacher as a guide. In addition, I included many articles that were not research based, but that proved to have valuable information that led me to other sources of research. I primarily included articles no later than the past ten years; however, I did include a few that dated back no earlier than 1985.

Chapter III

Literature Review

I organized the information in this chapter in alignment with the research questions. The questions provide a framework for the presentation and discussion of research. The research questions are the following:

1. What kind(s) of early childhood science instruction best support(s) student learning in science; and

2. What kind(s) of early childhood learning environment best support(s) student learning in science?

Current Problem

Both my own experience, and the research reviewed, agree that science education in early childhood faces three problems: 1) overemphasis on standardized testing and lack of clear standards at the state and national levels, 2) teachers' lack of understanding about the nature of science and inquiry, and 3) the failure of curricula to focus on crucial 21st century skills. When analyzing these three problems it can be a little overwhelming and seem as though teaching science through an inquiry-based approach can be very difficult with current school systems in place. However, our school systems are in need of repair and need to change rapidly to keep up with today's generation of students. The inquiry-based model fits in with today's objectives and tomorrow's goals.

Standardized testing and standards. With the ever growing emphasis on standardized tests teachers are losing quality classroom discovery time to practice for *the test*. The No Child Left Behind Act is at the center of controversy in education. While reviewing the issues Kenneth Jost writes"...both liberal and conservative critics say the eight-year old law has hurt education by overemphasizing standardized tests..." (Jost, 2010, p. 1). President Obama's plan, according to Jost, is for states to adopt national core standards developed by state leaders. The state of Iowa has developed the Iowa Core Curriculum, which has embraced inquiry as a model for teaching science. The Iowa Core Curriculum is a guide for Iowa school districts to align their curriculum to a set of concepts and skills that help to provide students with engaging curriculum that fosters deep levels of understanding and purposeful learning. In 2008, the state of Iowa passed Senate File 2216, which requires schools to implement the Iowa Core (Iowa Core Curriculum, 2011).

Lack of understanding about science and inquiry. Because the Iowa Core has embraced science inquiry as a model for teaching science, it is important for Iowa teachers to fully understand the nature of science and inquiry. The nature of science (NOS) refers to the "values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavor" (Schwartz, Lederman, & Crawford, 2004, p. 611). Scientific inquiry is defined as "...a range of philosophical, curricular, and pedagogical approaches to teaching. Its core premises include the requirement that learning should be based around students' questions" (Harvey & Daniels, 2009, p. 55).

Failure to focus on 21st century skills. It is important for our 21st century learners to be challenged and to be given opportunities to ask questions and seek answers. As teachers begin to engage their students in these essential skills and concepts of the Iowa Core they will begin to purposefully create learning environments in which students have opportunities to explore and investigate the curriculum at all grade levels; this will lead students to become more knowledgeable and confident in all academic areas (Partnership for 21st century skills, 2011).

We are failing our students and our future if we don't support student learning in ways that teach students how to seek out their own information. We tackle these skills and concepts through a scientific inquiry in the classroom. With teachers as the facilitators, we can guide and scaffold students to levels of understanding where we expect our students to be.

> Teaching science as inquiry is essential for student growth and development. School principals, district administrators, and teacher leaders (including department chairs) are essential links in the adoption of inquiry as a way of teaching and learning. Extensive research evidence gathered over many years points to the importance of leadership from principals and other building level administrators in improving the quality of teaching and learning in their schools. (Olsen & Loucks-Horsley, 2000, p. 143)

My goal is to find out what research says about how to do this effectively in an early childhood classroom and how to create an environment that supports inquiry through teaching and learning.

Evidence and Ideas Synthesized

I will provide evidence and support through reliable research and essays to provide adequate data to draw my conclusions regarding early childhood science instruction and environment. My goal is to share reliable information to provide the reader with sufficient information to draw conclusions and make informed decisions. The evidence and ideas have been synthesized and organized according to my questions regarding science instruction and environment.

What kind(s) of early childhood science instruction best supports student learning in science?

In this section, I will share research that describes inquiry-based and direct teaching models for teaching science, with the purpose of analyzing which model best supports student learning in the early childhood classroom. I looked at research that focused on teacher actions and pedagogy; however the research studies also addressed student learning as outcomes of the different studies—not just teacher change. The research provided quality evidence of positive strategies and interactions used by teachers to promote high levels of learning through inquiry-based teaching and learning.

Researchers Heal, Hanley and Layer discussed strategies that are located on a continuum of teaching strategies; this continuum supported the researchers in measuring the different levels of child engagement. The different points on this continuum are direct instruction (strategy 3), embedded teaching (strategy 2), and discovery learning (strategy 1). In this study the authors defined direct instruction as a teacher-initiated strategy. An example of this would be modeling the correct answers and reinforcing correct responses or preferred answers. They defined embedded teaching (located on the middle of the continuum) as target skills being delivered during child-initiated activities. An example of embedded teaching would be if the teacher provided materials for the students which provoked learning opportunities that reinforced target skills. The authors defined discovery learning as the discovery of new ideas with little or no guidance from the teacher. The learners were to construct their own ideas through independent interaction within their environment. The authors' example was when the teacher provides independent connections with learning materials with little interactions from the teacher. Their study focused on these three strategies and compared and contrasted their effectiveness and the style preferred by children. The participants were six children ranging from 48 to 61 months of age. The children attended a full day preschool classroom that served atypical and typical children. However, the researchers only worked with typical children. Children were selected based on the criteria of having informed consent of their guardians and consistent classroom attendance. The researchers gathered observational data on the children collected using paper and pencil within 15-second intervals. The researchers coded the different learning opportunities the children encountered during each style of teaching. The same teacher was involved in all three sessions using all three strategies. Students were pre-and post tested in a small room near their classroom to help compare and contrast student learning in each context. The researchers' goal was to provide evidence of which teaching procedure was most effective and preferred by children who were exposed to all three types of learning. They measured learning through a variety of pre- and post-assessments with the children through interviews. They measured teacher efficacy and student preference of the teaching content, which happened to be colors and animals in Spanish. These served as a measure of generalization for the acquired learning. They measured teacher efficacy and student preference by using 4 posttests involving 12 color- and animal-name relations. The researchers did a preassessment to find out if students had a color preference prior to collecting the data. They showed students the color cards in pairs and had the child touch the one they liked best. The researcher only said *thank you* in order to prevent showing any preference to any colors (Heal, Hanley & Layer, 2009).

When collecting data for strategy 1 the teacher sat with students with toys on a colored mat that corresponded to strategy 1. Since this was the strategy in which the teacher was unable to prompt children's responses, the teacher only held up the target stimulus and labeled in Spanish each item prior to the start of the session. All the interactions were child-initiated. If the child had a target response in 5 s (seconds) of the beginning of the learning opportunity, the teacher did provide affirmation; however if the child was wrong, the teacher would not correct him/her (Heal et al., 2009).

In strategy 2, the teacher sat with students with toys on a different color mat which corresponds with strategy 2. In this strategy the teacher was able to provide vocal prompts of the Spanish colors and animals when the learning opportunities began. The teacher also provided a correct response of the child who answered incorrectly when labeling an item. There was not any explicit instruction; however the teacher did provide praise when the student responded correctly. The two major changes from the first strategies are the different color mat associated with the strategy and the relations were not dictated to the child at the start (Heal et al., 2009).

Using the third and final strategy students sat across from the teacher using objects on a different colored mat which was associated with strategy 3. In this strategy the teacher explicitly taught the colors and animals through an echo response and modeling using the objects on the mat. Students also were rewarded with gold coins when the answered correctly (Heal et al., 2009).

The authors conducted a preference assessment with the students. They measured teaching preference through one-on-one interactions between each child and the teacher in the hallway for 30 to 60 seconds. On the outside of the classroom door were the three colors associated with the mats used with each teaching strategy. The child removed one of the colors from the door to experience that style of teaching with the teacher in the hall. They did this until each child experienced each style of teaching. The children learned to associate a Spanish color with each teaching strategy, which is how the authors post-tested students' preference. Based on the author's observations they found that children's level of engagement was significantly higher in the embedded lessons than in the other two types of lessons. Children appeared to learn more, as evidenced by higher numbers of correct answers on a recall task, in the embedded approach than in the other two approaches. Children had the highest number of correct learning responses and highest posttest scores after experiencing the embedded approach. Through their research the authors concluded that using a mixed approach was the best for teaching preschool children (Heal et al., 2009).

This study (Heal et al., 2009) failed to provide significant evidence and reliable data to determine that a mixed approach is the best for teaching preschool children. This study has too many variables that could have altered or changed the results in some way; for example, the use of colors and animals to determine the students' preference of teaching style. In strategy 3 the researchers rewarded students, which could have caused the color association rather than the teaching style or learning. Although the researchers attempted to prevent students from choosing a favorite color or animal, it is hard to determine that children were choosing a color or animals based on teaching preference alone. Another variable is the use of the teacher in Heal et al.'s research. The authors did not provide enough background information on the teacher involved in the study and the amount of professional development that was provided for the teacher. Failure to consider the teacher's normal style of interacting with children and personal preference regarding teaching may have had an effect on the results of their research. Due to lack of information and significant data it is difficult to make conclusions concerning the results.

Klein, Hammrich, Bloom and Ragins argued that in a discovery-oriented classroom using inquiry-based teaching, the teacher's role is to serve as a facilitator or guide for children by providing them with learning opportunities that will engage students in activities while interacting with their peers. This is very different from Heal et al.'s definition of discovery teaching, where the teacher is relatively inactive. According to Klein,et al., in discovery teaching the demands on the teacher are high and "teachers who are unfamiliar with the *facilitator role* may be uncomfortable and feel as though they are not teaching according to the curriculum" (Klein et al., 2000, p. 2).

Klein et al.'s research focused on developing children's language in addition to increasing teachers' questioning skills through the use of inquiry (Klein et al., 2000). They looked at what it took to develop a program of professional development on science inquiry in a Head Start program. Their research included two phases. Phase one participants were 18 preschool teachers, 11 classroom assistants, and 10 parents from 18 schools in Philadelphia and New Jersey. All participants in the experimental group received professional development which consisted of interactive inquiry-based training with the goal of broadening their science knowledge. The teachers were chosen by school principals after they had indicated interest in participating in this study. In Phase two the researchers expanded the research to include first grade students (N=98) in the first grade teachers' classrooms. There were four experimental classrooms in the fall 1999 and five in the spring 2000 totaling 14 classrooms. The control group had 10 classrooms in fall 1999 and 12 in the spring 2000. The teachers' aim was to expand on the children's knowledge about science and their conceptions around the three science domains; life science, earth science, and physical science using the inquiry-based teaching approach. Data were collected through surveys of teachers, teaching assistants, and parents. Onsite observations were conducted to classify the classroom's mode of interactions. The interviews of the participants involved semi-structured and open-ended questions about the classroom interactions. The authors used Degree of Implementation (DOI) scores to measure the dimensions met in each category. There were 12 areas or dimensions for degree of implementation. The authors' compared and contrasted the DOI in the fall and spring semesters with the experimental and control groups. The purpose of Klein et al.'s research was to change teachers' questioning strategies in a way that promoted student learning. Students in Phase Two were assessed on language comprehension and knowledge of science concepts, using unit pre-post tests for life, earth and physical sciences. These tests were developed by Hammrich and Klein (Klein et al., 2000).

The experimental group made significant gains in both content knowledge and application questions when compared to the control group. The average composite score for the four classrooms in the fall was 67.30 and the control group was 81.44. In the spring the experimental group was 87.50 and the control group was 81.73. These results showed that students in the experimental group, but not the control group, improved in their comprehension of language and knowledge of science concepts. The authors concluded that when children were given the opportunities to observe, predict and then justify their thinking, a deeper understanding of the concepts emerged and students were able to synthesize learning in a whole new way. The authors attributed the results in part to changes in teachers' classroom management strategies. According to the authors, teachers reported improvement in their classroom management after participating in the HSSC professional development, (Klein et al., 2000, p. 12). They defined classroom management as refining rules and procedures. The authors concluded that when classroom management and teachers' questioning strategies improve, it leads to improved student learning (Klein et al., 2000).

The authors' (Klein et al., 2000) description of their methodology lacked sufficient details and reflection. They failed to provide information about the control group and how it was chosen. Even though I was able to clearly understand the conclusions of the research, it was difficult to see the path that they took and therefore difficult to draw reliable conclusions based on the study's results.

Petersen and French conducted a study in which they compared and contrasted two teaching styles to see which style gave students the best understanding and conceptual knowledge. Participants were 47 students ranging from 3 to 5 years of age. Two lead teachers in separate classrooms were chosen to participate in the study because they were familiar with the *ScienceStart!* curriculum. The researchers conducted the study at a demonstration center for *ScienceStart!* curriculum. *ScienceStart!* is a curriculum for early childhood educators that emphasizes an exploratory approach that supports children's development of language, literacy, problem-solving, social skills, and self-regulation. This curriculum, developed by French through multiple grants, has been used in over 50 classrooms. Petersen and French collected their data by videotaping lessons. The authors coded and analyzed teacher modeling, children's observations, children's predictions, and children's collaboration. The authors were looking for patterns of interactions that were observed in the classrooms. They began their study with a teacher-directed style of pedagogy by holding up flash cards of colors and color names and having a call-response lesson on the colors with the students. Students gave one word responses with no explanation. When the children were given opportunities to mix colors along with the teacher and explore what happened, students began to understand how colors worked together along with the understanding that colors can be made from other colors. This suggested that when these students were given the opportunity to explore and ask questions, they developed a deeper understanding of color (Petersen & French, 2008).

The authors failed to describe how long the study lasted. In the absence of this information, it is difficult to make conclusions concerning the results. However, I believe Peterson and French made many valid discoveries that can motivate further research in the field.

Smith, Maclin, Houghton, and Hennesey's study measured sixth grade students' developmental progress focusing on the epistemology of science. This can be defined as a set of ideas students have about how knowledge is acquired and warranted in science. This study was designed to give students a sustained science curriculum in order to support students' thinking about science. The study involved a constructivist sixth-grade class of 22 students taught by Hennesey; the comparison school had two traditional sixth-grade classes that contained a total of 36 students who served as the control group; each class at the comparison school had the same science curriculum and science teacher. To assess the students' experience, the authors used an interview procedure called Nature of Science (NOS) developed by Carey in 1991 (Carey, 1991). This interview procedure includes questions about science goals, NOS questions, the role of experiments in science, the role of ideas guiding experiments, and the process of scientists carrying out research. Each question was recorded and scored a one, two, or three, based on the knowledge base of the response of the participant. Through this process they were able to determine an average score for each area. Smith and her colleagues found that students in the constructivist classroom were attentive to the central ideas being taught and they used those ideas to develop a deeper understanding of the content. An important piece of evidence which came from this study is that more students in the constructivist classroom (83%) had a deeper level of knowledge when compared with the students in the comparison classroom who were asked the same questions (37%). Students in the constructivist classroom had a better overall understanding of the content, as measured by students' awareness of deep explanatory questions in science (Smith et al., 2000).

This study also echoed what Klein et al. (2000) stated, which was when teachers improve their questioning skills they can enhance student understanding and deep conceptual knowledge. The authors (Smith et al., 2000) reflected on the importance of questioning in the early childhood level. This appears to be a critical piece when developing an inquiry-based science curriculum.

Schwartz, Lederman, and Crawford's (2004) research with pre-service teachers began with the idea that engaging in inquiry alone does not enhance nature of science concepts. Part of their research focused on the gap between NOS and scientific inquiry in K-12 classrooms while they also focused on the participants' views of NOS and their learning outcomes. The researchers' methods included separate roles for each researcher. Crawford designed and taught an internship course focused on science methods for classroom teachers. Lederman was a mentor in course design, and helped conduct and implement some of the research. Schwartz was the primary researcher. The participants were 13 fifth-year, secondary pre-service science teachers enrolled in the internship course as part of a teacher preparation program. The science research internship focused on the participants taking an active role in activities to teach NOS concepts. Each participant was paired with a scientist throughout the college to help them to identify NOS concepts and also identify misconceptions and apply these to K-12 education. The students also observed and interacted with researchers in order to gain new understandings about authentic research. Even though the participants were not school-aged children, the information gathered is still valuable to this review, because it demonstrated the importance of inquiry in the classroom.

The authors gathered data through questionnaires, interviews, journal entries, and participant observations. The participants were not a part of a K-12 setting, but rather were studying the effects of inquiry-based teaching and direct instruction within their research classrooms. They wanted to see what attributes a science course had that taught these skills. They examined authentic science inquiry, explicit NOS instruction and guided reflection. A secondary question that arose was what effects, if any, did this internship have on these pre-service teachers' teaching? They found that this process deepened 11 out of the 13 participants NOS understandings which the authors concluded could have an effect on their teaching in the future. Through this experience, pre-service teachers were actively engaged in activities, discussions, and demonstrations that were not only appropriate for K-12 learners but also to teach the NOS aspects of K-12 science education. Through careful investigations and gathering of the data the authors found that sometimes during direct instruction, teachers (all teachers, not just K-12) can lose out on *teachable moments*, which led the authors to conclude that teaching through an inquiry approach in a K-12 classroom should involve reflective practices and activities while explicit discussions enable a deeper understanding of the content or NOS within the classroom environment (Schwartz, Lederman, & Crawford, 2004).

This study (Shwartz et al., 2004) involved using pre-service teachers and their internship to focus on how to enable deeper understanding of the content through questioning skills and inquiry. It is important for teachers to use reflective practices to drive their instruction and to utilize teachable moments to help students better understand NOS concepts. However, due to the lack of student involvement with early childhood learners it is hard to relate the use of questioning skills and inquiry in relation to our early childhood learners.

Akerson and Donnelly (2010) conducted research that looked at a science program for 19 K-2 students. The authors developed a Saturday Science program designed to help students gain a new perspective on science. They focused their Saturday science program on helping students distinguish between observations and inferences. They used explicit reflective instruction, and emphasized the empirical, creative, tentative, and subjective nature of science. It was a six week program that ran for 2.5 hours a week. Students were taught science concepts through the science program. The researchers compared and contrasted student learning through pre- and post interviews with their overall goal being to find out if scientific concepts are too abstract for early childhood learners. The interviews were with small groups of students discussing their ideas and thoughts about NOS concepts. The authors found that it was difficult to pre-assess these young students' understandings because they are sometimes uninformed in the NOS concepts. Also, due to the nature of the group interview it was difficult to determine who knew what. This prompted the authors to move towards an individual interview format for the latter parts of the study. The researchers reported that K-2 students are able to conceptualize NOS aspects and make connections with these concepts and apply them to their daily lives (Akerson & Donnelly, 2010).

This study focused on K-2 students learning science concepts through the lens of nature of science. The researchers wanted to learn whether students at this level were able to conceptualize the NOS aspects and make any sort of connections with them. According to their results, students were able to conceptualize NOS aspects, however they have many misconceptions about science. The researchers did fail to report how students were selected to be a part of this program and how they were divided into their interview groups. The lack of detail and support in this area could provide inadequate reliability in the data (Akerson & Donnelly, 2010).

A study by Khishfe and Abd-El-Khalick (2002) examined the effects of explicit and reflective inquiry-oriented teaching and compared this with an implicit inquiry-oriented instructional approach with sixth graders. Each model focused on the sixth-graders' understandings of nature of science (NOS). The explicit group engaged in many kinds of inquiry activities that were followed by reflective discussions focused on some

NOS aspects; the comparison group was involved in the same inquiry activities without any discussion after the activity. The components within the study concentrated on different aspects of NOS. The participants were 62 sixth-grade students in two groups. At the beginning of the study each of the 62 students completed the survey. Next, samples of 16 students, 8 from each group, were chosen for individual interviews to validate the questionnaire. The authors used a six-item open-ended questionnaire along with individual interviews to assess the students' views on NOS aspects. The research lasted 2.5 months. When it was finished the same questionnaire was administered to all 62 students. The same 16 students were interviewed for a second time. The questionnaire was taken under the supervision of a teacher and it took about 45 minutes for the students to respond. According to the authors, the scores of the students in the explicit group increased between the pre-test and the post-test, while the scores of the students in the implicit group did not change. The authors concluded from these findings that students' NOS views could be enhanced when teachers target the NOS aspect of science activities and embed NOS within inquiry activities. The authors noted that when inquiry is used in isolation (that is, when students are engaged in exploration and discovery only, without reflecting or mini lessons to expand thinking or new understandings) aspects of NOS are not learned. However, the authors failed to describe how participants were assigned to the groups. The lack of evidence could affect the validity of this research (Khishfe & Abd-El-Khalick, 2002).

A study by Akerson and Abd-El-Khalick (2005) concentrated on how students' views align with the national expectations of teaching science. The focus of their study was on one fourth grade class of 23 students and their scientific understandings and questions. The fourth grade teacher engaged students through meaningful scientific inquiries, such as studying water quality and designing their own water quality tests. This allowed them to seek their own information by allowing them to raise their own questions related to what they were studying in class. The researchers collected data through pre- and post interview questionnaires. The interviews took place at the end of the school year. All 23 students participated in a modified View of Nature of Science---Form B questionnaire. This is the same questionnaire used by Khishfe and Abd-El-Khalick (2002). The purpose of the questionnaire was to assess students' NOS views. Then eight students were chosen to participate in follow-up interviews. The interviews took place in a quiet area outside of the classroom, lasted about 45 minutes, and were tape-recorded for accuracy. Results indicated that these fourth-grade students did not have an understanding of the NOS concepts after the teaching with inquiry. According to the authors these findings suggested that students relied too much on direct observations to create their understandings of NOS concepts rather than making inferences from indirect observations; these findings suggested that inquiry instruction alone doesn't teach NOS concepts (Akerson & Abd-El-Khalick, 2005).

I believe due to the small number of participants (especially follow-up interview participants), the conclusions are far from valid. Based on my experience at a laboratory school, students are very much able to draw conclusions from indirect observations, and that through inquiry, students are able to learn nature of science concepts. I agree with Akerson and Abd-El-Khalick that students do rely a lot on direct observation, but I do not see the problem in that. We teach our students to observe and draw conclusions whether directly or indirectly from the observation. The researchers Heal et al., (2009) and

Khishfe and Abd-El-Khalick (2002) viewed inquiry as a teacher's hands-off approach. However, other researchers, such as Klein et al. (2000) and Smith et al., (2000) viewed inquiry as a teacher facilitator approach. The difference in these perspectives and approaches can influence how and what children learn.

Forbes and Zint (2011) conducted a study that investigated elementary teachers' thoughts on scientific inquiry and the process students go through when learning about environmental issues. The data were collected with a questionnaire given to a random sample of elementary teachers in and around a Midwestern university community. The researchers sent out 752 surveys to elementary teachers and 121 responded. The survey instrument, designed specifically for this study of elementary teachers (K-5), consisted of three sets of 10 questions, for a total of 30 questions. Their questions focused on learning about the environment through an inquiry approach. The data showed the respondents were more likely to engage in scientific inquiry if they perceived themselves as science learners and thus more likely to engage their students in these practices. This study also suggested that most of the surveyed teachers wanted to engage in teaching with an inquiry-based approach; however time seemed to be one of the biggest issues. The researchers stated that this was a cause for concern and time needs to be given to students who are engaged in inquiry (Forbes & Zint, 2011).

Other researchers extended the debate of inquiry versus direct instruction in a recent study. Coburn, Schuster, Adams, Applegate, and Skjold et al. (2010) carried out a research study about scientific concepts with eighth grade students during a summer camp. The research took place in the summers of 2007 and 2008 with upcoming eighth grade students in several Midwestern school districts. Students' families chose if they wanted to be involved in the camp and in the study. The authors created two learning models: one to be taught using direct instruction and one to be taught using the inquiry method of teaching. The teachers chose which method they wanted to teach based on what they felt comfortable teaching. The researchers gathered data using independent observers by a Science and Mathematics Improvement (SAMPI) group who specialize in evaluating science instruction. The SAMPI group, who were unaware of the teacher's mode of teaching, evaluated the teacher's performance data. In addition, independent observers who were also blind to the teacher's chosen model visited the class for two lessons per unit and each of the two observers saw each teacher. They documented instruction and scored the fidelity of the model they observed. The observers examined teachers' notes, lesson plans, and overall teaching practices. They used a seven point scale to analyze each teacher's fidelity. The average score for this study was a five. According to the authors' research there were not any significant differences among the different teaching methods. They concluded this could be the result of different teachers, different topics, and the different modes. Therefore they concluded that inquiry and direct models of teaching lead to about the same conceptual understandings during the same instructional time (Coburn, Schuster, Adams, Applegate, Skjold, 2010). The researchers failed to disclose how many teachers were in their study and how they specifically measured student outcomes. They described using a 7-point scale to measure teacher fidelity, but failed to describe what the measures or scores mean to the study. I also believe their definition of inquiry-based learning and what it looks like differs from the definition used in this review. The authors of this research defined inquiry as active learning but failed to clearly define the teacher's role in this approach. Due to these reasons Cobern et al.'s study (2010) has reporting flaws that make it difficult to draw accurate conclusions.

Dean and Kuhn conducted a study to explore how practice activities with direct instruction compare to direct instruction alone. Participants were 45 fourth-grade students from an urban elementary school. The school enrollment is unique and consists of 50% university faculty and senior administrators' children and 50% from lower income neighborhood families selected to attend through lottery. The authors compared and contrasted the learning outcomes for students who were assigned to one of three groups: the control-of-variables (PR) strategy, control-of-variable strategy with direct instruction (DI/PR), and direct instruction (DI) without any engagement or practice. The control-of-variable strategy (PR) means engaging students in a problem while providing them with the opportunity to construct a strategy to solve the problem. The authors worked with the students over 12 sessions through a ten week program. They measured student learning through three computer-based inquiry tasks used for practice and assessment. They assessed students four times through the research project, and conducted an ANOVA to determine between-group differences, but to also look at comparisons. One of the comparisons they looked at was direct instruction and performance over time in regards to the assessment tasks. The authors' findings were that fourth-grade students were able to produce a significant level of correct performance after a brief direct instruction (DI) lesson. The authors found that students' learning was lower in the DI group than the PR group, but not significantly; this did lead the authors to conclude that direct instruction is not necessary for long term learning and teaching in science. The PR/DI group at the end of the study scored slightly below the PR group. .

Student scores were highest in the PR group, lower in the PR/DI, and lowest in the DI group, but none of these reached significance. However, the researchers did conclude that there was no real significant difference in student learning based on their assessments of a longer time frame, which means even though there were some differences in learning, it wasn't significant enough due to the time frame. The authors stated in their side note that they did not look to the maintenance over time nor did they look at the transfer of information (Dean & Kuhn, 2006).

This study suggested that direct instruction may not produce deeper learning and conceptual knowledge, at least in this setting, and using the methodology of this study over time. Perhaps, as seen with the other studies (Klein et al., 2000; Peterson & French, 2008; Smith, 2000; Tu, 2006) presented in this review, inquiry-based instruction does provide deep conceptual knowledge when guided by a teacher who focuses on complex thinking rather than drill and repetition and when time is provided for high quality inquiry to take place. The researchers of this study did not focus on long term understanding, but perhaps if they had, they would have found the same results as the others.

Although some of these researchers are looking at the methods used to teach science, they have failed to look at what methods provide a deeper understanding of the content, rather than simply looking at which is better at memorizing facts. Khishfe and Abd-El-Khalick (2001) noted that the scientific inquiry approach alone does not teach the nature of science concepts. However, Peterson and French's (2008) research strongly suggested that children's explanatory language increased when engaged in inquiry-based teaching and learning. As seen in other studies (Dean & Kuhn, 2006, Heal et al., 2009, Klein et al., 2000) described in this chapter, the question of how the researchers defined inquiry learning, and the amount of teacher facilitation and engagement with students during their inquiry could have a produced a large effect on results. There may be other factors that can alter the results of a study, such as length of the study, time devoted to teaching with an inquiry approach and short and long term understandings and gains in content.

I shared research that described the inquiry-based and direct teaching models. The research I looked at focused primarily on teacher actions and pedagogy; however the research studies also addressed student learning as outcome of the different studies—not just teacher change. The research provided quality evidence of useful strategies and interactions which can be used to promote high levels of learning. These were to provide a classroom that encourages questioning skills and supports discovery learning. Some of the research did state that direct teaching produces better learning, however the research conducted did not look at the learning over time.

What kind(s) of early childhood learning environment best supports student learning in science?

I will discuss both the physical environment and the psychological environment, as both are important aspects that support student learning in science. Both aspects are critical to the development of a rich learning environment that supports early childhood science learning.

Physical environment. Science is the way children discover and understand how our world works (Tu, 2006). Tu (2006) investigated 20 preschool classrooms and examined their science learning environments. She looked at what was available to children in regard to materials, equipment, and activities. Each teacher was videotaped during the children's free play time. The author used three instruments to assess the classroom environment and teacher interactions within the environment: the Preschool Classroom Science Materials Checklist, Preschool Classroom Science Activities Checklist, and the Preschool Teacher Classroom/Sciencing Coding Form. Tu looked at what the teacher was doing and how the teacher could improve science activities and instruction for the early childhood learners in ways that create a learning environment that promotes discovery. When coding the classroom science area Tu looked at nine areas: art, blocks, computer, manipulatives, science, dramatic play, language and reading, and sensory. She documented where the teacher was interacting with children in these areas of the classroom environment. According to the author, the findings were that the majority of classroom activities were not science related. Some results from the study showed that 65% of the classrooms in the study had a sensory table and only 55% of the classrooms provided some sort of water or sand activities. The author later reflected on the importance of science exploration areas within the classroom. She expressed that teachers should allow students individually or in small groups to explore, predict, analyze and synthesize at their own pace. Tu also concluded that when teachers introduce daily science activities and use this time for *teachable moments*, this practice promotes science discovery and further understanding. Tu finished by stating that for our schools to improve on science teaching, our teachers need to reflect on their own practices *and* utilize the science materials that are available to them (Tu, 2006). Tu also discussed the importance of having open-ended materials that promote student thinking and wonderment, as well as the importance of having a teacher who supports inquiry and discovery. This is critical to a successful learning space, because the teacher plays a key role in how the children perceive themselves as learners. Teachers "can model with their children a passion for discovery that is common in the world of science" (Tu, 2006, p. 251). Klein also made this point, observing that this occurs when teachers not only ask "questions of students but also encourage students to ask questions for clarification, to understand that learning takes time, and to understand that mistakes are accepted when followed up with new information to solve problems" (Klein et al., 2000, p. 6).

Zan and Escalada (2011) described a project for young children in the area of physical science education. Their goal was to provide a physical science curriculum for pre-k-2nd grade that would result in higher science achievement through an age-appropriate physical science curriculum; this would allow students to develop an understanding of force and motion, scientific inquiry, engineering, and positive attitudes towards science. They also wanted to develop a set of materials that early childhood educators can use in their own classrooms to promote this style of teaching and learning. The study began with a pilot-test with 19 local teachers and then expanded to a field study with three sites across the country. The teachers involved were engaged in professional development through week-long summer workshops in which they learned the physics concepts, explored hands-on learning, and created their own learning community. These learning communities were supported through regular meetings each month during the following school year. Data were collected using a variety of methods. The authors used qualitative and quantitative measures to examine the impact made on teachers and students. They assessed teachers' implementation of the project through observation of the classroom and teacher interviews, and they examined children's pre-post gains in understanding of force, motion, and inquiry using an active interview and a teacher-report checklist. According to the authors' research, their findings suggested that the majority of the teachers participating in the Ramps and Pathways project demonstrated a high degree of fidelity, which suggests that when teachers are given adequate professional development, materials for a rich environment, and support, then they can provide students with an environment that supports inquiry-based learning and teaching (Zan & Escalada, 2011). It is important to note that several of the primary grade classrooms involved in this study were also located in *Reading First* schools where classroom instruction was mandated to focus substantially on reading throughout the school day.

Writing about the Ramps and Pathways project, Zan and Geiken stated that "it is very important to set up a classroom environment in which children feel safe trying their ideas without fear of failure" (Zan & Geiken, 2010, p. 15). This means children should not worry about failing, but rather feel safe in attempting to learn something new. Their essay described how to set up an active and engaging science exploration activity using ramps and pathways. Both writers are educators who have spent numerous years providing professional development for teachers as well as observing children in science activities. They developed the Ramps and Pathways project in a laboratory school located near a university in the Midwest. The laboratory school primarily serves students from minority cultures and low-income families (Zan & Geiken, 2010). They described how children need to work together to build their communication skills with their peers over time. This style of environment allows students to experiment with their ideas and begin to process their discoveries. It is important for teachers to create environments that inspire investigation and promote questions and discovery (Zan & Geiken, 2010).

Psychological environment. Yoon and Onchwari wrote in their 2006 essay about teaching young children science. The authors discussed how science is a great subject for increasing brain development in young children, which makes the teaching of science that much more critical to early childhood teachers. Their essay focused on three key points of creating a successful science learning environment: developing appropriate practice, using the 5E model, and using questioning strategies. The 5E instruction model (Engagement, Exploration, Explanation, Elaboration and Evaluation) allows teachers to guide children to learn through problem solving. The authors argued that when students are provided with a rich environment using these key points, children are able to engage with science (Yoon & Onchawari, 2006).

In another rich essay, Chalufour, Hoisington, Moriarty, Winokur, and Worth (2004) provided examples of a quality classroom environment that is supported with inquiry by building block structures. Children in Boston learned science and math concepts while building with blocks. This is a very typical activity in a preschool classroom; however what differed was how the teacher set up the environment to provide a rich learning place for all learners. The teacher not only changed the physical aspects of the room by making the block area larger, adding foam and cardboard to the area, and using tabletop blocks, but she also created an environment in which she facilitated questions and inquiry. The teacher engaged students in questioning that deepened their quest for practical knowledge of how blocks work, encouraged students to represent their data in multiple modes to help articulate their new understandings, and used formal and informal conversations to help students solidify their information. The authors stressed that when looking at the environment it is important to focus not only on the items in it, but also the people. Teachers can take advantage of *unplanned experiences* to be used as teachable moments (Chalufour, Hoisington, Moriarty, Winokur, & Worth 2004).

Peterson and French's research looked at how teachers were providing support in their curriculum to adequately teach students about colors. They compared and contrasted different methods in teaching. They found it is important for the teacher to provide an environment that models inquiry through the students' oral language skills. Through modeling, students begin to investigate learning and find a new understanding of the content. Teachers need to support children in this learning environment in order to increase student explanatory language (Peterson & French, 2008). Cobern et al. echoed this statement in their research by stating, "inquiry based instruction potentially offers significant advantages to science education, by modeling science inquiry..." (Cobern et al., 2010, p. 93).

I discussed the physical environment and the psychological environment. The evidence provided in these articles and research studies demonstrate that when setting up a space that supports and guides learners, teachers need to devote attention to both the physical and the psychological environment, as both are important aspects that support student learning in science. This means as a classroom teacher you need to provide your students with open-ended materials that provoke thought and questions. A learning environment is more than the four standing walls; it is the teacher who makes the environment a purposeful place to learn and discover through an inquiry-based approach.

The teacher is purposeful and knowledgeable, but not afraid to say “I don’t know, let’s find out together” (Peterson & French, 2008; Tu, 2006).

Chapter IV

Conclusions

In this chapter, I present my conclusions, identify and synthesize my insights, suggest recommendations for teachers, administrators and future researchers, review education policies, and share my own teaching practices and future research. My purpose is, by returning to my research questions, to provide adequate and useful information to inform educators about the practices and environment surrounding science inquiry at the early childhood level.

The findings from three studies (Klein et al., 2000; Peterson & French, 2008; Smith, 2000) demonstrated that many researchers in the field believe it is particularly important to develop students' inquiry skills and understandings early because these views can provide a motivating and empowering foundation on which to build their science understanding and learning. Through all of the research and new understandings of scientific inquiry I conclude that it is important to allow students the opportunities to grow through discovery as well as to facilitate their learning through questioning and scaffold their learning through an inquiry-based approach (Klein et al., 2000; Peterson & French, 2008).

The early childhood science instruction that best supports student learning in science is inquiry-based instruction (Klein et al., 2000; Peterson & French, 2008). It is important for educators to support student learning instruction through questions and ample time to explore materials and phenomena. The findings of Yoon and Onchwari's (2006) study pointed to the importance of teachers having an inquiry-oriented classroom. They suggested you will seldom see the teachers telling students the answers, but will often see them questioning the students (Yoon & Onchwari, 2006). It is important for teachers to scaffold learning through children's own questions and motivations for learning. This means that the teacher works as a guide to facilitate a learning environment that meets the needs of all learners. This enables students to be motivated in their own learning, creating a deeper understanding of the content.

Recent researchers have also found that often early childhood classroom teachers have many missed opportunities to enhance and develop children's inquiry skills (Klein, et al., 2000; Tu, 2006). It is important for classroom teachers to understand the value of children asking questions, as well as looking for the answers. Children have an innate curiosity about the world around them and naturally ask questions. Teachers can develop students' questioning skills by facilitating an environment to encourage exploration and discovery. Teachers' overall objective would be that these inquiry skills will later translate into the other academic areas and will motivate students in their own learning endeavors.

Based on Tu's (2006) findings about the science learning environment, it appears that teachers need to create an environment for their students that is open-ended and in which teachers guide, support, and scaffold children through questioning, while keeping students engaged and motivated (Tu, 2006). This provides further evidence that discovery learning with little or no adult guidance is not very effective (Dean & Kuhn, 2009; Akerson & Abd-El-Khalick, 2005). These are the optimal moments where the teacher will teach what students need to know at the moment they need to know it. This is when students have the most valuable and purposeful understanding and deep conceptual knowledge of the content.

I agree with Zan and Escalada (2011): not only do we need to provide our teachers with adequate materials to conduct a beneficial classroom environment, but we must also support them through professional development. Based on my experience, I believe this is one of the key aspects missing from our school systems when it comes to building a supportive inquiry-based learning environment.

Identification and Synthesis of Insights

What kind(s) of early childhood science instruction best support(s) student learning in science? When beginning my journey with inquiry it was critical for me to explore and learn how to best meet the needs of all of my students. This thinking process has helped me to conceptualize what I was doing in my own classroom and how I was impacting student learning each and every day. My teaching practices are constantly a work in progress and I am consistently making changes and tweaking how and what I do with my students. This is critical to my development as a *teacher learner* as well as the development of the learning for my students. The research included in this review has stated that students and teachers who are involved in an inquiry-based classroom environment may have a deeper understanding of the content and concepts being taught than having a classroom using direct instruction alone (Akerson & Donnelly, 2010; Forbes & Zint, 2011; Klein et al., 2000; Peterson & French, 2006; Smith, 2000; Tu, 2006).

Peterson and French's study primarily looked at preschool science learning in a Head Start classroom. They concluded that making meaning through explanations and discoveries needs to be central part of the teaching and learning within the classroom (Peterson & French, 2008). This means it is better for young children to understand how science works by posing their own questions than to confirm the results of what has already been concluded. Based on their research, Peterson and French (2008) concluded that "children who participate in explanatory discourse with adults in preschool stand a greater chance of meeting this challenge in later grades" (Peterson & French, 2008, p. 406). Based on Peterson and French's results, I believe that if students have opportunities to explain and discuss their ideas in preschool, they will be better able to clearly explain their ideas later.

The findings from three studies (Klein et al., Peterson & French, 2008, Smith 2000) have led me to believe that inquiry-based teaching and learning is the best way for students to learn science. It allows students to develop their own understanding of the concepts, while examining and building on questions and thinking processes (Klein et al., Peterson & French, 2008, Smith 2000). Even though some of the research was conducted with older students, other researchers have demonstrated that the process of inquiry teaching and learning, defined as including engagement with the teacher as facilitator, is applicable to younger students as well.

What kind(s) of early childhood learning environment best support(s) student learning in science? Science inquiry is more than children playing with open-ended materials; rather it involves a classroom of learners learning together and from one another, with the goal of creating a new understanding of the concepts they are exploring. It is the teacher's role to facilitate and guide students on this journey of learning. It is important, if not critical, for teachers to be provided with support and encouragement from their administration to give students the time and *freedom* to explore learning in a risk-free environment. This means that students are given the opportunity to process, wonder, and discover, based on their own individualized differences and needs. This allows the teacher to teach each and every student at their optimal learning point and provide them the best opportunity for learning (Chalufour et al., 2004; Bosse et al., 2009; Tu 2006).

Implementing inquiry-based teaching starts with the teacher and his/her teaching style. However, teachers need support, guidance, and leadership which are vital if we want teachers to make “a major shift from a traditional didactic style of teaching to one that emphasizes inquiry” (Olsen & Loucks-Horsley, 2000, p. 143). As noted by many researchers, creating an inquiry-based atmosphere in an early childhood classroom sets the stage for later learning endeavors (Akerson & Donnelly, 2010; Forbes & Zint, 2011; Klein et al., 2000; Peterson & French, 2006; Smith, 2000; Tu, 2006). It is important for early childhood educators to provide an environment that enables students to think for themselves and learn from their experiences. The early childhood learners should be constructing their own knowledge through experiences and hands-on activities (Tu, 2006).

Based on Forbes and Zint’s research, it appears that educators need to be supported by their administration and schools to conduct an inquiry approach curriculum. Teachers need time and resources to provide students with an environment that supports and challenges each and every student. Forbes and Zint’s research led them to conclude that teachers need to feel comfortable and confident in teaching with an inquiry-based approach. Teachers need to feel trusted by their school administrators to take risks in their own teaching and learning (Forbes & Zint, 2011).

Based on Zan and Escalada's (2011) findings, it appears that children's attitudes towards science increased while being in an inquiry-based learning environment. This suggested that when children are learning science in an environment that embraces inquiry-based teaching, they are more likely to want to do science (Zan & Escalada, 2011).

I believe the environment in which children are engaged needs to support their psychological needs as well as their physical needs. The findings from two studies converged on the point that teachers need to be supported in an environment that allows them to take the time to spend on teaching science through an inquiry approach (Forbes & Zint, 2011; Tu, 2006). I believe having a supportive environment means supporting the teachers through continuous professional development and providing them with materials that provoke thought and discovery in children.

Recommendations

While reviewing the research I have found some critical pieces needed to promote inquiry-based teaching in the early childhood classroom. I have meticulously looked over a wide variety of research that has been included in this review, and also took into account the knowledge and experience from my own early childhood classroom teaching.

I recommend the following in order to promote inquiry-based teaching within the early childhood classroom learning environment:

- Teachers need to demonstrate good questioning skills and discovery for students so they can learn how to investigate and form good questions (Tu, 2006). This will likely require professional development activities about questioning skills.

- Teachers need to be inquisitive themselves and question what and why they are teaching the way they are. When students are given basic information to begin their own questioning, their curiosity for continued exploration expands (Klein et al., 2000).
- Teachers need professional development that provides deep understanding for the process of learning rather than simply the product. It is important to help teachers utilize the science materials they already have within their classrooms to promote questions and discovery (Tu, 2006).
- Teachers need to change the teaching, assessment, and learning environment in their classrooms to include a greater focus on inquiry.
- Teachers need more evidence on how "students initially find out or are told about science concepts and laws, various knowledge elements and connections need to be revisited while making sense of these concepts and laws" (Cobern et al., 2010, p. 92). Teachers and administrators need to understand and seek evidence of how to best teach science concepts and skills.

Future research is needed to inform efforts to support early childhood students' learning through inquiry in the context of elementary science education, particularly those based on observations of actual classroom practices (Forbes & Zint, 2011). Currently there is not adequate research to convince teachers and administrators how this can happen. We need to conduct more research to study how best to teach, assess, and help students learn through inquiry (Peterson & French, 2008). Teachers also need more research in this area due to the limited amount of research in this age group in general. Our smallest of learners can inquire and synthesize information about the world around them. We need up-to-date research that provides evidence and concrete examples to help change our schools.

Future Projects

Some future projects that can be researched by Iowa's Research and Development School, Head Start or other parties of interest would be the connections of inquiry-based instruction and the increase of learning and understanding in other curricular areas. The research reviewed in this paper has led me to believe that when students are engaged in inquiry-based instruction, not only does their science understanding increase but also their understandings in other curricular areas. It would be beneficial to the state to review these findings, with the hope that state officials, school administrators and teachers would see the need for science inquiry education in each and every classroom.

Educational Policies

According to Peterson and French's conclusions, most preschool curricula do not even support scientific inquiry. Also with the passage of No Child Left Behind in 2001 many states have heard the call for early learning standards and have developed a plan for our early learners. They all include science learning and explorations as the means. However our current preschools are looking more like kindergartens and our current kindergartens look much like first grade. This type of teaching focuses on basic skills, rather than creativity and exploration (Peterson & French, 2008).

Teacher Practices of Self and Others

Some future projects for myself include becoming involved teaching the Center for Early Education in Science, Technology, Engineering and Math (CEESTEM) modules to early childhood and elementary educators around the state of Iowa. This will provide teachers around our state with hands-on resources which they can use in their own classrooms. In addition, this would allow me to demonstrate to others my passion for and commitment to inquiry based teaching, and I can share how I have been able to implement inquiry teaching and learning into my own classroom.

I am also going to conduct an action research project in my own classroom involving the ideas presented in this review. I think it is important for our early childhood educators to be aware of the capabilities of our young children and how we can best meet their educational needs. Peterson and French stated, "Children [become] scientists, taking an active and systematic approach to learning about the world around them" (Peterson & French, 2008, p. 406). My goal is to provide teachers with the support and evidence that children can and do investigate, discover and synthesize about science concepts and skills through an inquiry-based approach.

I began my love for science long ago when I was a child, but since beginning my career as a teacher it has become who I am and how I teach. "Science is part of our everyday lives, and everyday is filled with science possibilities" (Bosse et al., 2009, p. 14).

I have presented my conclusions, identified and synthesized my insights, suggested recommendations for teachers, administrators and future researchers, reviewed education policies and shared my own teaching practices and future research plans. My goal was to provide concrete evidence to support inquiry-based learning and an environment that supports all learners, as well as to identify where further research can be conducted. The research reviewed has strengthened my resolve to both use and support others' use of science inquiry at the early childhood level.

References

Akerson, V., & Donnelly, L. (2010). Teaching nature of science to k-2 students: What understandings can they attain? *International Journal of Science Education, 32*(1), 97-124.

Akerson, V., & Abd-El-Khalick, F. (2005). "How should I know what scientists do?--I am just a kid": Fourth-grade students' conceptions of nature of science. *Journal of Elementary Science Education*, *17*(1), 1-11.

Bosse, S., Jacobs, G., & Anderson, T. L. (2009). Science in the air. *Young Children*, *64*(6). Retrieved from http://www.naeyc.org/yc/pastissues/2009/november

Carey, S. (1991). *The nature of science interview.* Unpublished manuscript.

Chalufour, I., Hoisington, C., Moriarty, R., Winokur, J., & Worth, K. (2004). The science and mathematics of building structures. *Science and Children, 41*(4), 30-34.

Chalufour, I., & Worth, K. (2003). *Discovering nature with young children.* St.Paul, MN: Read Leaf Press.

Cobern, W., Schuster, D., Adams, B., Applegate, B., Skjold, B., et al. (2010). Experimental comparison of inquiry and direct instruction in science. *Research in Science & Technological Education*, *28*(1), 81-96.

Dean, D., & Kuhn, D. (2007). Direct instruction vs. discovery: The long view. *Science Education*, *91*(3), 384-397.

Dictionary.com Retrieved July 6, 2010, from Dictionary.com website: http://dictionary.reference.com/browse/inquiry

Early Childhood Research and Practice. (2011). Retrieved from http://ecrp.uiuc.edu/

Eisner, E. W. (1994). *The educational imagination: On the design of evaluation of school programs* (3rd ed.). Upper Saddle River, NJ: Merrill/Prentice Hall.

Forbes, C., & Zint, M. (2011). Elementary teachers' beliefs about, perceived competencies for, and reported use of scientific inquiry to promote student learning about and for the environment. *Journal of Environmental Education*, *42*(1), 30-42.

Funk, H., Fiel, R., Okey, J., Jaus, H., & Sprague, C., (1985). *Learning Science Process Skills, (2nd ed.)* Dubuque, IA: Kendall/Hunt Publishing Company.

Gestwicki, C. (2007). *Developmentally appropriate practice: Curriculum and development in early education, 3rd Edition.* Clifton Park, NJ: Delmar.

Harvey, S., & Daniels, H. (2009). *Inquiry circles in action*. Portsmouth, NH: Heinemann.

Hickman, L. (1997). Inquiry: A core concept of John Dewey's philosophy. *The Freedom to Inquire.* Retrieved October 17, 2009, from accessmylibrary: http://www.accessmylibrary.com/article-1G1-19417758/inquiry-core-concept-john.html

Heal, N. , Hanley, G. , & Layer, S. (2009). An evaluation of the relative efficacy of and children's preferences for teaching strategies that differ in amount of teacher directedness. *Journal of Applied Behavior Analysis*, *42*(1), 123.

Inquiry-based education. (1997). Retrieved October 17, 2009, from Inquiry-based Education Website: http://archive.ncsa.illinois.edu/Cyberia/DVE/FusionDVE/html/inquiry_based_education.html

Iowa Core Curriculum. (2011). Retrieved from http://www.corecurriculum.iowa.gov

Jost, K. (2010). Revising No Child Left Behind. *CQ Researcher*, *20*(15), 337-360.

Khishfe, R., & Abd-El-Khalick, F. S. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39,* 551–578.

Klein, E., Hammrich, P. L., Bloom, S., & Ragins, A. (2000). Language development and science inquiry: The head start on science and communication program. *Early Childhood Research and Practice*, *2*(2), Retrieved from http://ecrp.uiuc.edu/v2n2/klein.html

Merriam-Webster Online Dictionary. (2010). Retrieved July 21, 2010, from http://www.merriam-webster.com/dictionary

The National Association for the Education of Young Children. (2011). Retrieved from http://www.naeyc.org

National Science Teachers Association (NSTA). (2007). NSTA position statement. *The integral role of laboratory investigations in science instruction.* Retrieved from http://www.nsta.org/about/positions/laboratory.aspx

Olsen, S., & Loucks-Horsley, S. (2000). *Inquiry and the national science education standards: Guide for teaching and learning.* Washington, D.C.: National Academy Press. Retrieved on July 19, 2010, from http://www.nap.edu/catalog.php?record_id=9596

Partnership for 21st Century Skills. (2011). Retrieved from http://www.p21.org/index.php

Peterson, S. M., & French, L. (2008). Supporting young children's explanations through inquiry science in preschool. *Early Childhood Research Quarterly, 23.* doi: 10.1016/j.ecresq.2008.01.003

Price, T. (2008). Science in America.*CQ Researcher*, January 11,2008, pp. 25-48.

Schwartz, R. S., Lederman, N., & Crawford, B. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645.

Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction, 18,* 349–422.

Tu, T. (2006). Preschool science environment: What is available in a preschool classroom? *Early Childhood Education Journal, 33*(4), doi: 10.1007/s10643-005-0049-8

Yoon, J., & Onchwari, A. J. (2006). Teaching young children science: Three key points. *Early Childhood Education Journal, 33*(6), 419-423.

Zan, B., & Geiken, R. (2010). Ramps and pathways: Developmentally appropriate, intellectually rigorous, and fun physical science. *Young Children, (65)*1, p. 12-17.

Zan, B., & Escalada , L. (2011, April). *Ramps and pathways: Evaluation of an inquiry-based approach to engaging young children in physical science.* Paper presented at the annual conference of the American Educational Research Association, New Orleans, LA .