2017

The value of inquiry-based science instruction for elementary students

Jessica Renae Enger
University of Northern Iowa

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Abstract

This review examined the academic benefits of using inquiry-based science instruction in elementary classrooms. It also examined different ways teachers integrate inquiry-based instruction. Several studies identified increases in science content knowledge, concepts, and process skills as outcomes associated with inquiry-based instruction. Other studies in this review showed mixed or negative results for academic benefits of inquiry-instruction. This review also highlights hands-on investigations, discourse, and literacy as three ways teachers integrate inquiry. Findings of this review suggest inquiry-based instruction allows students to understand difficult science concepts, justify their ideas, and can create positive attitudes toward science.

The Value of Inquiry-Based Science Instruction for Elementary Students

A Graduate Research Paper

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

Jessica Renae Enger

December 2017

This Research Paper by: Jessica Renae Enger

Titled: The Value of Inquiry-Based Science Instruction for Elementary Students

has been approved as meeting the research requirement for the

Degree of Master of Arts in Early Childhood Education.

12/14/17
Date Approved

Betty Zan
Graduate Faculty Reader

12/14/17
Date Approved

Mary Donegan-Ritter
Graduate Faculty Reader

12/14/17
Date Approved

Deborah Tidwell
Head, Department of Curriculum and Instruction

ABSTRACT

This review examined the academic benefits of using inquiry-based science instruction in elementary classrooms. It also examined different ways teachers integrate inquiry-based instruction. Several studies identified increases in science content knowledge, concepts, and process skills as outcomes associated with inquiry-based instruction. Other studies in this review showed mixed or negative results for academic benefits of inquiry-instruction. This review also highlights hands-on investigations, discourse, and literacy as three ways teachers integrate inquiry. Findings of this review suggest inquiry-based instruction allows students to understand difficult science concepts, justify their ideas, and can create positive attitudes toward science.

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CHAPTER I

Introduction

"From a very early age, children interact with their environment, ask questions, and seek ways to answer those questions. Understanding science content is significantly enhanced when ideas are anchored to inquiry experiences" (NSTA Position Statement on Inquiry, 2004).

In his article on the history of inquiry, Barrow (2006) traces the term inquiry as used in K-12 science education back to John Dewey in 1910. John Dewey, a science teacher, philosopher, psychologist, and educational reformer, proposed the use of inquiry to allow students to have a more active role in their learning instead of simply memorizing science facts. Dewey thought the teacher's role was to facilitate the students' learning by prompting them to ask questions, helping the students test their hypotheses and analyze and revise their findings (Barrow, 2006).

Today inquiry has many different titles such as problem-based learning, discovery learning, STEM, or hands-on investigations. Too often when educators hear the word inquiry they simply think of hands-on learning. However, the report done by the Early Childhood STEM Working Group (2017) argues that is only one of many elements needed for inquiry to trigger student's active thinking and conceptualizing. Another confusion surrounding the implementation of inquiry-based instruction is what the teacher's role is. Some interpret it to mean the students design and conduct the investigations independently while others believe the teacher needs to facilitate their learning, which is sometimes referred to as guided inquiry. Despite the debate on the teacher's role or the different names used for inquiry, the act of inquiry itself involves several essential components. When students are engaged in inquiry-based science lessons they are: (a) asking questions about phenomena, (b) creating investigations to answer their questions, (c) making predictions, (d) observing and collecting data, and (e) analyzing and sharing what they learned (NRC, 1996).

In this chapter, I describe the importance of scientific inquiry and the effect inquiry has on educational and social domains. I then explain why research on inquiry-based science instruction is important and how the results of this review will contribute to student's science outcomes and enhance teacher instruction. I then list and define some important terms that appear in this paper. Finally, I state and explain the research questions that guide this paper.

The Importance of Inquiry-Based Science Instruction

Science plays an integral role in all aspects of our lives: medicine, weather, food, and even our communication. It allows us to understand our world in order to create a better future. Therefore, it is critical that we prepare students to pursue science=related fields and compete in an increasingly scientific and technological world. In Iowa alone STEM fields make up 15 % of the job opportunities. Yet in 2014-2015 about 8,744 STEM jobs were left unfilled (Governor's STEM Advisory Council, 2015-2016). Many business owners state that today's children lack the problem-solving, reasoning, and communication skills to make them employable (White, 2013). Not all students will grow up to be scientists; however, we need to prepare them to be productive citizens who can use critical thinking and communication skills to make informed decisions.

To combat these issues the NGSS adopted new standards. These standards use inquiry to teach students about scientific content and the scientific process. This includes scientific reasoning and other practices that are relevant not only in the science classroom but also in the real world. When teachers use inquiry-based instruction it can provide children with important reasoning skills that can impact society and have many educational benefits for children.

Inquiry is rooted in the constructivist belief that children are active participators who co-construct knowledge through talk and exploration of materials. Supporters of inquiry-based instruction believe when children construct their own knowledge through inquiry they have a deeper understanding of science phenomena which allows them to apply that learning to new contexts. They also argue students can retain that science knowledge better through inquiry learning than direct instruction (Bredderman, 1983; McDaniel & Schlager, 1990; Schauble, 1996; Stohr-Hunt, 1996). The constructivist theorist Jean Piaget claimed, "each time one prematurely teaches a child something he could have discovered for himself, that child is kept from inventing it and consequently from understanding it completely" (Piaget, 1979, p.715). Unlike traditional direct-instruction that has been criticized for contributing to students' negative attitudes toward science, inquiry-based instruction sparks students' science interests and curiosities (Shamsudin, Abdullah, & Yaamat, 2013).

In addition to increases in student motivation for science, inquiry-based instruction has been shown to significantly increase students' understanding of science content and increase student science scores (Granger, Bevis, Saka, & Southerland, 2009; Banilower, Fulp, & Warren, 2010). Studies also show inquiry can lead to higher reading and math test scores (Governor's STEM Advisory Council, 2015-2016). Inquiry-based instruction allows children to make sense of the world around them instead of learning science in isolated pieces.

Improving Science Instruction in Elementary Classrooms

I chose the topic of inquiry-based science instruction because I know the important benefits science has for the future of our country and I have seen how empowering it is when students take ownership of their learning through discourse and problem-based tasks. As a first grade teacher, I implemented a STEM scale up program to teach content on simple machines. I was amazed to see how invested the students were in the real life problem of creating a new toy for a toy company and how that positively affected my test scores.

However, as an educator I have also seen first-hand how undervalued science is in elementary school. About four years ago I transferred to a new school district as a kindergarten teacher and was shocked to find out none of their science was aligned to the Iowa Core and there were no student assessments. In fact, teaching and reporting on science was not mandatory. Instead teachers had thematic units about seasons and holidays. I realized the mandates the government created on reading and math scores caused all instructional time, intervention time, and professional development to focus solely on reading and math. If a student failed to learn science content, re-teaching had to be done by parents at home because there was no additional time for re-teaching science.

Science in lower elementary typically consists of describing observations because science inquiry is considered too difficult and a better fit for older students (American Association for the Advancement of Science, 1993; National Research Council [NRC], 1996). Many trends suggest that young children's science ideas and explanations are unsophisticated because they use personal experiences to make sense of science phenomena (Edwards, Gandini, & Forman, 1993; Gallas, 1994; Gopnik, Meltzoff, & Kuhl, 1999; Paley, 2009). According to Siry & Kremer (2011) however, young children develop science understanding through many complex interactions. These interactions include experiences with phenomena, getting information from texts or different media, their imaginations, and through conversations. In fact, early experiences in science help mold their view of science, promote later participation, and increase their desire to pursue STEM careers (Jurow & Creighton, 2006; Governor's STEM Advisory Council, 2015-2016).

Eighteen states in the United States and the District of Columbia have adopted the Next Generation Science Standards for students in grades K-12 in order to help teachers make sure science instruction is preparing students for college and career success. The new standards are three-dimensional performance expectations that combine science and engineering practices, cross cutting concepts, and disciplinary core ideas. I chose this topic because my school district is in the process of writing curriculum to support the new NGSS. We are expected to implement one unit this year and the rest the following year so I wanted to know more about what quality science instruction looks like in elementary school.

Research shows teachers dislike science because they do not know how to effectively teach it. "Teachers' and parents' lack of content knowledge and fear of STEM topics can result in avoidance of teaching, talking, and thinking about challenging STEM topics" (Early Childhood STEM Working Group, 2017, p.17). Therefore, learning about the effective use of inquiry-based science in implementing the new NGSS will be valuable for principals who are creating professional development to support teachers. School districts will also be looking at what resources to spend money on to help with implementation of these standards so knowing the effective/ineffective elements will ensure it goes to the right places.

Effective Science Instruction to Enhance Student Outcomes

Education policies are constantly changing and bringing new criteria for teachers to implement and adopt. Due to this educators do not always have the best attitudes about change and therefore, are hesitant to implement new things. The findings of this review could potentially help educators see the reasoning and/or benefits behind inquiry-based science instruction by showing the importance of incorporating more science and shifting educators' focus strictly from reading and math. Teachers can gain ideas on how to design science lessons that integrate literacy and math skills and meet the new components of NGSS. Finally, findings can assist principals in supporting teachers as they implement the new standards.

Currently large sums of money are being invested in STEM education. Therefore, many policy makers want to know the impact of STEM education. This review examines the impact of inquiry on student outcomes. In addition educator preparation programs can gain ideas about how to better prepare teachers for inquiry-based instruction in teacher undergraduate programs.

Terminology

For the purpose of this paper I am defining the following terms to support the reader's understanding:

Direct Instruction- an instructional approach where students receive explicit teaching on science content, procedures, and skills from the teacher typically through modeling or lecturing

Inquiry-Based Instruction- an instructional approach that allows students to develop an understanding of science knowledge through questioning, designing and conducting experiments, basing conclusions on the analysis of experimental data, and reporting findings (NRC, 1996).

Problem-Based Learning- an instructional approach where students are given a real-world problem and work collaboratively with teacher assistance to solve the problem (Zhang, Parker, Eberhardt, & Passalacqua, 2011).

Guided Inquiry- An instructional approach that increases the amount of teacher involvement in inquiry instruction to support student learning when the subject matter is complex and challenging. Teachers may also use materials and peer support to assist student learning in guided inquiry (Decristan et al., 2015).

Discourse- the making of meaning through the use of verbal and nonverbal communication (Arnold, 2012).

Phenomena- natural events students can observe and can use science to explain why the events happened or predict what will happen

Inquiry Process Skills- students' ability to ask questions, make predictions, analyze data, and draw conclusions

Research Question

This literature review analyzes the research on the most effective practices in elementary science instruction with a particular focus on inquiry-based instruction. he following questions guided this review:

1. What are the academic benefits of inquiry-based teaching of science in kindergarten through fifth grade?
2. How do elementary teachers implement inquiry-based science teaching?

CHAPTER II

Literature Review

With the adoption of the NGSS, Iowa's schools are shifting their focus toward the importance of science and how to successfully implement it. Teachers, principals, and educational policy makers need to know the effective strategies for teaching science that will develop students into critical thinkers and problem solvers. This review of research examines the different benefits of using inquiry-based science instruction in elementary classrooms and the different ways elementary teachers integrate inquiry-based instruction. The following chapter addresses these research questions:

1.What are the academic benefits of inquiry-based teaching of science in kindergarten through fifth grade?

2.How can elementary teachers implement inquiry-based science teaching?

This literature review is organized by my two research questions. The first section examines the benefits of using inquiry. The second section examines how teachers implement inquiry into science instruction. Finally, I summarize the findings from the articles.

Academic Benefits of Science Inquiry

This section examines research on the academic benefits of implementing inquiry-based science instruction in elementary. It is broken down into two sub-sections. The first section looks at how inquiry might increase students' content knowledge and their science process skills. The second section looks at how inquiry increases students' use of content vocabulary and deepens their conceptual understanding.

Increasing Science Content Knowledge and Process Skills

Minner, Levy, and Century (2010) did a research synthesis to uncover the impact of inquiry science instruction on K-12 students' understanding of science facts, concepts, and principles. They analyzed articles written between 1984 and 2002 that had at least one student instruction or intervention in science that involved an element of inquiry and reported student outcomes. Minner et al. found 51 % of the studies showed inquiry-based instruction had a positive influence on students understanding of science content and retention. However, 33 % of the studies with inquiry-based instruction had mixed results and 16% of the studies had no effect or had a negative effect for student learning (Minner et al., 2010). Contradictory to their hypothesis the researchers also found that there was no correlation between the amount of inquiry in a study and positive student outcomes on science concepts (Minner et al., 2010). Results from studies that compared students in a treatment group that received more inquiry-based instruction to results of a control group who received less were positive toward inquiry-based instruction. In 23 studies the treatment group did significantly better. In five studies the results were inconclusive. In nine studies there was no statistical difference between groups and in one study the treatment group did statistically significantly worse (Minner et al., 2010, p. 490). In four studies where multiple groups were given the same amount of inquiry-based instruction and pre/post scores were analyzed, all groups did statistically significantly better on the post assessment. One study that compared direct instruction to inquiry-based instruction found directly afterwards students scored similarly but two weeks later the students in the inquiry-based instruction held onto the conceptual learning. The study also showed the learning-disabled students in the inquiry-based instruction group scored higher on the two-week performance based assessment than their learning-disabled peers who received direct instruction (Minner et al., 2010, p. 491). Six studies found a statistically significant increase in student conceptual learning when students had more input in designing investigations and instruction. One limitation from this synthesis is the wide span of teachers (experience, professional development, style), attitude and comfort with science: these differences could also have played a part in the impact of the results based on how they delivered the information to students. Another limitation was the wide variety in the definition of inquiry and what it looks like to implement inquiry-based science. Many studies state they have inquiry-based instruction but they are missing many key elements of inquiry. Researchers need to agree on the specific elements needed to qualify as inquiry instruction and include information about these elements in their methodology. Then more research needs to be done to assess the effects of inquiry-based instruction on elementary and early childhood students' science learning. Some studies also had the instructor teaching the experimental and comparison group which could skew the results and many of the studies had marginal methodological rigor.

Aydeniz, Cihak, Graham, and Retinger (2012) conducted a study with three 5th-grade students and two 4th-grade students to see the effects inquiry-based curriculum had on students' conceptual and application-based understanding of simple electric circuits. All of the students qualified for special education services for reading and two also qualified for math. The intervention used *The Electric Circuits KitBook*, (Edamar, Inc., 2008) a hands-on curriculum that uses activities and quizzes to teach scientific concepts such as (a) simple circuits, (b) conductors and insulators, (c) parallel circuits, and (d) electricity and magnetism. The intervention took place in the students' resource classroom but was taught by the students' classroom teacher. The five students met daily for 50-minute sessions. During the first 20 minutes the students took a quiz that covered conceptual-based and application-based problems over the four science concepts. The students were assessed through these quizzes that were semi-randomly assigned with different problems. The researchers calculated the students' percentage by dividing the number of problems answered correctly by the total number of problems presented in the 20 minutes. A stable baseline was configured for each student after a minimum of five sessions. During the remaining 30 minutes of the intervention the teacher went over vocabulary, asked questions, helped students make connections to electricity, and partnered two to three students together to work on the simple circuits experiments. Once the students achieved 100 % on two quizzes covering simple circuits then they repeated the intervention but moved to the next concept: conductors and insulators. This was repeated for each science concept. The results from each assessment showed students content knowledge increased. The findings from the intervention quizzes showed problems about simple circuits went from an average correct of 4.7 percent at baseline to 76 percent during the intervention. Conductors and insulators average baseline was 5.5 percent correct and jumped to 81.5 percent correct. Students' baseline average for parallel circuits was 6.8 percent correct. They improved their average to 87.5 percent correct during the intervention. Six weeks later students were assessed using probes that covered the four science concepts. Findings showed all five students retained the information learned from the intervention. Before the beginning of the intervention and again at the end of the study the students were also given the Scientific Attitudes Inventory SAI-II (Moore & Foy, 1997), which measured their attitude toward science. After the intervention, students showed significant improvements on attitudes toward science. A limitation of this study is the size; more research would need to be done in order to make any generalizations. Another limitation was the effect the increased amount of science instruction had on the students' outcomes. The inquiry-based curriculum was in addition to the students' regular science instruction, so it is unknown if the students would have the same results if this replaced their other science instruction. Based on the results the researchers propose that students with learning disabilities can increase their conceptual understanding and positive attitude toward science through the use of science kits in inquiry-based lessons. (Aydeniz et al., 2012). More research needs to be done to determine how effective it is for younger students and with other discipline areas for science.

Patrick, Mantzicopoulos, and Samarapungavan (2009) conducted a study of 162 kindergarteners from three midwest suburban public schools to examine the influences of gender and type of science instruction on young children's motivation for science. Kindergarten students in one school received regular instruction where science was incorporated in weeklong themes through art and stories. The other two schools' kindergarten students participated in the Scientific Literacy Project. SLP is a program that teaches the big ideas of science through a process where students investigate phenomena, analyze findings, and reflect (Patrick et al., 2009). The authors examined three adjacent schools to make sure they had similar academic and demographic information. Then teachers and students were invited to participate in the study. One school implemented SLP for five weeks and the other implemented SLP for 10 weeks. The authors did not provide information concerning how schools were chosen. The SLP lessons lasted 60 minutes and took place twice a week. In the SLP lessons students created investigations, with teacher guidance, to answer questions they had about science phenomena. During the investigations the students would make observations, collect evidence, and afterward share their results in discussions. Teachers also incorporated nonfiction texts to support learning. The Puppet Interview Scales of Competence in and Enjoyment of Science (PISCES; Mantzicopoulos, Patrick, & Samarapungan, 2008) measured students' beliefs about science competence, science liking, and science process skills such as their ability to ask questions or make predictions. Findings showed statistically significant differences on all three subscales: science competence, science liking, and science process skills for the SLP type of instruction. The SLP inquiry based science groups had a higher mean than the regular instruction group for beliefs about science competence and science process skills. Students who received regular instruction did not like it as well as students who received SLP inquiry-based science. Students in the regular instruction group tended to rate themselves lower on science competence than students in the SLP groups. When examining the effect of gender and type of instruction the researchers found overall there was no significant difference but there was a significant interaction effect for gender and the type of instruction the students received on the science liking subscale. Boys in the regular science instruction classroom liked science more than girls but in the SLP inquiry-science classroom there was no difference between the sexes. This research is promising because it shows students who participate in inquiry-based instruction are more engaged to learn, which can lead to a better understanding of the topic (Patrick et al., 2009). A limitation could have been the difference in the amount of time spent on science in the SLP groups versus the regular instruction. The SLP groups received 120 minutes of weekly science instruction whereas the regular instruction teachers reported they tried to fit science in some each week. More research needs to be done on how students' behaviors towards science change as they progress through school and experience the regular type of science instruction vs. inquiry-based science.

Samarapungavan, Patrick, and Mantzicopoulos' (2011) study of 185 kindergarten students in half-day programs from four Midwestern suburban public schools found that inquiry-based instruction can have a positive impact on students' abilities to use science process skills. The researchers selected six kindergarten classes from two schools to participate in the intervention group that received inquiry-based instruction through the Scientific Literacy Project. The intervention group was chosen because four of the five teachers leading the intervention group had piloted SLP activities the year before. The teachers were provided extensive support through the SLP project. The year prior to implementation the teachers met several times with the researchers to develop activities and materials. The teachers were given materials that included: instructional goals, examples of ways to introduce and scaffold activities, science information that linked to the activities, and websites with additional science information. Throughout the implementation year each SLP teacher was assigned a research assistant who helped monitor student activities and met weekly with the teacher for 30 minutes and before each new unit. At these meetings, the SLP teacher and research assistant would troubleshoot and discuss implementation. The intervention classrooms participated in the Scientific Literacy Project throughout the school year. Based on similar demographics and achievement information two schools were chosen in the spring by the researchers to be the control group. The control group was comprised of four kindergarten classes that received regular instruction.

Students in the SLP group received a 60-minute lesson twice a week that included 3 components: (a) pre-inquiry, (b) inquiry, and (c) post-inquiry. During pre-inquiry the teacher checks students' background knowledge and introduces the investigation. During the inquiry phase students conduct investigations, gather data, and analyze findings. In the post-inquiry phase students reflect and share their learning in class discussions (Samarapungavan et al., 2011). The SLP group had six units that lasted a total of 20 weeks spread out over a year. Students in the control group received regular science instruction where the teachers tried to fit it in when they could. The teachers chose their own topics, however most of them picked topics that connected to cultural or seasonal events. The science activities often involved hands-on activities and making crafts such as making insects with Twizzlers or making grass people. Some teachers also reported using nonfiction texts and sorting activities for science. The Electronic Portfolio (Samarapungavan et al., 2008, 2009) was used to assess artifacts of the students' learning during the SLP activities. Students in the control group did not use the Electronic Portfolio as an assessment measure because their instruction method did not produce enough artifacts. The Electronic Portfolio contained student artifacts such as students' science notebooks, class idea boards, and scanned posters. It also contained SLP class digital videos and transcripts that were entered by the child's name, class, unit, and activity (Samarapungavan, Patrick, & Mantzicopoulos, 2011, p. 424). That way when the researchers typed in a student's name all the student's artifacts for evidence of learning would come up.

The researchers used a rubric to look for evidence of student learning using six measures: (a) raises questions/makes predictions about the natural world, (b) engages in observation and recording of data, (c) communicates about investigations using words or pictures/drawings, (d) understands and can give examples of the relationship between biological structure and function, (e) understands and can give examples of how species are adapted to their habitat, and (f) understands and can give examples of patterns of biological growth and development (Samarapungavan et al., 2011, p. 424). A 0-3 scale was used to rate each child's portfolio artifacts. A score of 0 meant the child had no data evidence to meet the measure and a score of 3 meant 2 or more artifacts showed the child could demonstrate the measured skill independently. The Science Learning Assessment-Version 2 (SLA-V2) (Samarapungavan et al., 2008, 2009) was also administered to assess the students' understanding of the processes of scientific inquiry and scientific content. Students in the intervention group took the SLA-V2 before starting the intervention at the beginning of the year and again at the end of the year. Since students in the control group were not selected until spring they only took it at the end of the year.

Evidence from the portfolio showed the inquiry group progressively increased their proficiency in science process skills over time. In unit two 4 students were proficient or higher on raising questions and making predictions but by unit six 83 students were at proficient or higher (Samarapungavan et al., 2011). The portfolio also showed students also increased their life science content knowledge. The SLA-V2 findings showed the SLP inquiry group had statistically significant differences in pre and posttest Total scores, Inquiry Process scores, and Science Content scores. On the pretest students answered on average slightly less than half of the questions correctly but on the posttest the average of correct responses rose to about 75 percent. The results also showed SLA-V2 Inquiry Process questions covering making predictions, asking science questions, and testing hypothesis were more difficult than the content questions for both groups (Samarapungavan et al., 2011, p. 458). However, the Inquiry Process mean scores from the SLA-V2 increased from 3.54 out of 9 on the pretest to 6.94 on the posttest for the inquiry group. The comparison group's mean Inquiry Process score was 3.46. A limitation for this study is that there was no baseline data for the comparison group. Another limitation was that the comparison group collected no portfolio evidence due to their instruction method. The comparison teachers also stated they used hands-on activities, which are often thought to be interchangeable with inquiry-based teaching. More research needs to be done on the elements of inquiry-based instruction to help teachers define inquiry-based instruction and understand how to implement its elements. The researchers concluded that their results are important because they contradict numerous research that suggests students' understanding of the process of scientific inquiry is very restricted at the elementary age (Samarapungavan et al., 2011).

In a study by Zhang, Parker, Eberhart, and Passalacqua (2011), a veteran kindergarten teacher implemented problem-based learning (PBL) to 24 kindergarten students to determine the effects it had on their content knowledge about Earth science. Over the summer the kindergarten teacher participated in a two-week professional development program that focused on content and how to design PBL units. She also met once a month with teachers to research and analyze their work. The PBL lesson launched from the teacher reading the book: *What's so Terrible About Swallowing an Apple Seed?* The class then had a discussion of the problem of the story: can an apple seed grow in your stomach. The teacher created a chart about what the students knew and questions they had. The students read books, watched videos, and conducted apple-planting investigations to answer their question about what an apple seed needs to grow. Lastly the students participated in a whole group discussion to share what they learned. Data was analyzed from classroom videos of PBL lessons and teacher-created student assessments. Findings showed that the design of the PBL inquiry lessons allowed students to develop their science process skill of questioning. Analysis of student scores from the pre-test to post-test showed students' content knowledge increased because their abilities to include the key components needed for seeds to grow increased. The assessment also showed all PBL students were able to name at least one correct Earth material. Compared to the previous year's students that received regular instruction in Earth science, the students in PBL could explain more key components and had fewer misconceptions. In addition the previous year's students who received regular instruction had 28 out of 66 correct answers on the teacher created assessment while the PBL students had 65 out of 72 correct answers (Zhang et al., 2011, p. 476). One limitation of this study is its small size. It was only one unit in one kindergarten class, thus more research needs to be done. Another potential limitation is the lack of information about the previous year's students; that is, the author failed to describe how the students in the previous year's class and students in this year's class compare academically and demographically. There could be other influences on the outcomes besides the teaching method. The teacher had a lot of implementation support through professional development; another research question to think about would be whether or not the amount and type of professional development affects the outcomes.

Another study that looked at the effects of inquiry-based science instruction on students' science process skills was done by Cotabish, Dailey, Robinson, and Hughes (2013). Cotabish et al. (2013) conducted a study in two school districts with 70 teachers in second through fifth grade to determine the impact a STEM intervention had on students' science process skills and science content knowledge. The authors' STEM Starters intervention offered professional development for teachers on how to implement an inquiry-based science curriculum that has problem-based learning units. Teachers were randomly assigned to the treatment group or the control group. The intervention group consisted of 813 students. For this study the authors chose the William and Mary science curriculum as the inquiry-based science curriculum for the STEM Starters intervention. The intervention lasted for nine weeks. Teachers who taught the intervention group received 30 hours of professional development in the summer and 30 hours of one-on-one professional development with a weekly peer coach during the school year. The professional development centered around how to implement inquiry instruction, understand the problem-based curriculum, engage students with technology, and improve their science knowledge. Intervention students in grades 2 and 3 focused on the concept of change within weather and matter content and intervention students in grades 4 and 5 focused on the concept of systems within electricity and acid content. The control group consisted of 932 students who received the standard science instruction that was part of the schools' curriculum. To measure students' science process skills they used the Scoring Rubric for Scientific Processes—Adapted Fowler Test (Adapted from Fowler, 1990). Students in the intervention group had a statistically significant gain in science process skills over the control group. The intervention group could construct science experiments for authentic problems and make scientific connections using overarching concepts such as change and systems more easily than the control group. To measure student learning of science content the students were given pre and post curriculum-based assessments that scorers used a rubric to rate. Findings showed the students in the intervention group showed statistically significant gains in science concepts and science-content knowledge. Although the authors provided detailed information on the STEM Starters intervention and curriculum material, they failed to provide any details on the regular science instruction for the control classroom; it is unclear what content, methods or strategies were used. Cotabish et al. conclude this study shows the positive effects in-depth professional development and inquiry-based science instruction can have on student outcomes. Further research needs to be done with younger students and special education students to see if they would have similar data

Increasing Vocabulary and Understanding of Science Concepts

Van Hook, Huziak, and Nowak (2005) conducted a study to determine if hands-on inquiry-based lessons would help kindergarten students develop mental models of air. One of the difficulties of teaching science to elementary students is how abstract many of the concepts are. They often require students to infer information that cannot be observed directly. To make science concepts more concrete teachers often need to help students create mental models (Van Hook et al., 2005,). The study took place in a midwestern town with 39 kindergarten students in half-day programs. A scientist taught seven 30-minute lessons using hands on activities and songs. The scientist's goal was to create a mental model for the students to understand the concept of air. In the first lesson the students had to come up with evidence for the existence of air. The following six lessons included investigations where the students developed the "balls of air" mental model and used it to understand air in different contexts. The investigations included (a) knocking over and moving objects with ping pong balls, (b) comparing how fast flat paper and crumpled paper drops, (c) learning about surface area with parachutes, (d) "Mouse Bowling" experimenting with weight and air resistance, (e) investigations on air pressure using straws, (f) and learning about Newton's Third Law using fan cars. The researchers analyzed pre- and post-interview responses and videotapes of body language for themes. Findings showed that in the pre-interview most kindergarten students used their prior experiences to answer questions about air and justify their explanations. For example, a majority of students said air was wind and explained it was real because they could feel it. Twenty-five percent of the students said they did not know what air was made of. Post-interview data showed more students were able to explain what air was and what it was made of, and used the model to explain their thinking. After the investigations more students used deeper explanations that included mechanisms and new language. In the pre-interview only one-fourth of the students knew air was in an empty bottle compared to two-thirds that knew in the post-interview. The authors pointed out the inquiry-based lessons were not enough for all students to use the mental model to shift their thinking in the post-interview. Some students relied heavily on the scientist for affirmation of their reasoning. The researchers concluded the inquiry-based lessons helped most kindergarten students learn not only about air but also how to apply knowledge of air in different contexts. This study suggests that young children can explain and scientifically justify an idea and that inquiry can help them create mental models to understand air. A limitation is the size of the study. More studies need to be done to see if young children can create mental models to help them understand abstract concepts in the different science disciplines.

Van Hook & Huziak-Clark (2008) conducted a study of 49 half-day kindergarten students to determine if inquiry-based lessons could increase students' understanding of energy. The kindergarteners received five 30- minute lessons structured around the 5E model: Engage, Explore, Explain, Extend, and Evaluate. The lessons included: (a) hands on exploration, (b) whole-group discussions, (c) demonstrations on how toys use energy, (d) and songs and key phrases about energy. After analyzing pre and post interviews for codes and patterns the researchers found most students could distinguish between where energy comes from and how it is used. Kindergarteners were also able to give examples of living things and inanimate objects that use energy. In the post interview students used more vocabulary from the discussions and included more reasoning in their thinking. One question from the interview asked the students how to put energy into a plastic bunny and a wind-up toy. In the pre-interview very few students were able to put energy into the plastic bunny but in the post-interview all students were able to give the bunny energy by pressing down on it causing it to hop. The authors concluded "kindergarten students are capable of developing basic understandings of energy if they are provided with hands on experiences that relate to their own lives" (Van Hook & Huziak-Clark, 2008, p. 12). One limitation of this study is the limited number of participants; more replications would need to be done. Another limitation was that a scientist taught the lessons to the kindergarten students. A classroom teacher might not have the background knowledge or confidence to create or facilitate some of the experiments.

Varma's (2013) study of 64 students from two first-grade classrooms and two third-grade classrooms from a private elementary school examined the impact inquiry-based learning had on young children's understanding of thermodynamics. Two teachers in first and third grade volunteered to participate in the study. One class from each grade level was randomly assigned the experimental class or the control class. Students in the experimental group partook in guided experiments in the school's conference room during recess or free choice time. In pairs the experimental students participated in three investigations where they made observations, collected and recorded data, made predictions, and tried to solve problems. In the first investigation they explored thermal equilibrium and heat flow using a bowl of room temperature water, a warm bottle of water, a cold bottle of water, and a handheld computer. During the last two investigations students learned about insulation and heat flow. In one investigation they had to use different material to keep juice cold and in the other investigation they had to choose from the same material and keep hot chocolate hot. An experimenter was in the conference room with the students facilitating the investigations by prompting the students to make predictions and helping with data collection. The experimenter also explained thermodynamics and heat flow to the students and prompted them to make connections to it during the investigation. Between February and April, intervention students participated in three lessons. The control classes received no instruction on the topic and never saw the experimental room. Varma used a pre- and post-test open-ended clinical interview to measure student learning. The interviews were transcribed for coding and data analysis. Findings showed that over time the guided experiments allowed first and third graders to learn about the concept of thermal equilibrium. She also found students in the experimental group possessed more complete mental models for thermodynamics than students in the control group. Posttest scores showed 63 percent of third graders in the intervention group increased their understanding of heat flow compared to 36 percent of the third graders in the control group. Likewise, 57 percent of the first graders in the intervention group increased their understanding of heat flow compared to 0 percent of the first graders in the control group. Findings also showed that students in the experimental group gave more answers than the control group that contained no misinformation when identifying and explaining good insulators, however, it was not statistically significant. The authors concluded that the instructional content was attainable for younger students because the thermodynamic and heat flow investigations built off of pre-existing experiences of keeping things hot and cold and the inquiry-based learning motivated students to become active learners (Varma, 2013). Varma pointed out further research needs to be done to determine which aspect of the intervention increased student learning: (a) scaffolding from the experimenter, (b) the investigations, (c) the materials, (d) or a combination. One limitation of this study was that the control group received no instruction on the topic; this may have skewed the results. I think it would be important to replicate the study but have the control group receive direct instruction on the topic for comparison. The size of the study also limits the results.

Integration of Inquiry-Based Science

Inquiry-based instruction is considered best practice throughout the science community and has been endorsed by the National Science Teachers Association. Often teachers know what type of instruction to use but how to implement it in the classroom is difficult. The following sections show how teachers use (a) hands-on investigations, (b) discourse, and (c) the integration of literature and science to implement inquiry in the classroom.

The Role of Hands-on Investigations in Inquiry

In Minner, Levy, & Century's meta-analysis the authors explained how inquiry-based instruction emerged from viewing instructional materials from a constructivist perspective. They explain how hands-on investigations are an important part of these materials inquiry because the investigations make science concepts more concrete and motivate student learning (2010, p. 475). NSTA also recommends that elementary students should participate in hands-on explorations as part of the inquiry process to develop deep understanding of science concepts and skills. Teachers and students can work together to create investigations to understand science phenomena. Many times the material teachers select for students to manipulate can help clear up misconceptions and promote deeper discourse on science content.

Slavin, Lake, Hanley, and Thurston (2014) conducted a research synthesis to look at how different science instruction affects achievement outcomes for elementary students. They included 23 studies from 1980-2012 that met the following criteria: (a) evaluated programs or practices in elementary science, (b) focused on K-5 students, (c) lasted at least four weeks, (d) compared children taught in science class using science program/practice with a control using an alternate program/method, (e) used random assignment or matched adjustments for pretest differences, (f) included quantitative measures of science performance, (g) had at least two teachers with 15 students in each group, and (h) the assessments given had to cover content taught in both experiment and control groups (Slavin et al., 2014, p. 875). The researchers used effect sizes as a summary of outcomes on each measure. The sample size was used to weight the average effect size in order to determine the treatment effects for the results. Findings showed studies where teachers used science kits to implement inquiry-based lessons resulted in limited student achievement. Some well-known kits such as *STC, Insights, Project Clarion, and Teaching SMART* resulted in no positive achievement for students. Overall science kit programs mean effect size was only +. 02. However, one of many studies that evaluated FOSS did result in a positive influence. The authors pointed out one reason for these results may be teachers tend to focus more on the implementation of the kit materials and less on increasing students' science understanding. Ten studies of inquiry-oriented programs without kits that involved a vast amount of teacher professional development did show positive science outcomes on stringent evaluations with a weighted mean effect size of +0.36 (Slavin et al., 2014). The professional development from these studies centered on effective science teaching, conceptual challenge, cooperative learning, science-reading integration, teaching scientific vocabulary, and using the inquiry learning cycle (Slavin et al., 2014, p. 895). A major limitation of this synthesis was the small number of studies (23) that met the criteria. More studies need to be done to determine effective science methods for elementary students. Some of the studies were done in other countries, so results may change if implemented in the United States.

Siry and Max (2013) conducted a qualitative study of 26 four- to six-year-olds to determine how children's questions and interests could be used to develop hands-on science investigations. The study took place in a multi-age kindergarten class in Luxembourg. The class decided to investigate water using an aquarium tank. The teacher put different objects next to it for the students to explore. Through exploration the students notice a crayon changes the color of the water. This led to an investigation with crayons in different bowls of water. The teacher supported learning with questions and facilitated discussions about findings. Researchers analyzed video recordings, student photography, and student video recordings looking for themes and theme co-construction. Episodes where themes emerged were analyzed further for deeper interpretation. Findings showed that children created sinking and floating and wave investigations with the water. "…The children and teacher co-constructed understanding of the phenomena related to water, as they discussed, questioned, and observed together" (Siry and Max, 2013, p. 897). By having an open-ended curriculum, the teacher enabled the students to play an active part in creating their science curriculum. This study suggests young children are capable of investigating complex problems and designing their own investigations (Siry and Max, 2012). One limitation of this study is its size. Continued research needs to be done to show how to involve students in the process of science learning but still meet science standards.

Klahr and Nigam (2004) conducted a study of 112 third and fourth grade students to determine the effectiveness of discovery learning and direct instruction on students' understanding of control of variables (CVS). Students from four elementary schools, one of which was an all girls' school, were randomly assigned direct instruction or discovery learning for the study that lasted two days. On day one both discovery and direct instruction groups performed a baseline exploration experiment with a ramp and different types of balls. The students were asked to create four experiments that showed how steepness and ramp length effected how far balls would roll. A score was given to the student for all unconfounded experiments created. Then teachers in the direct instruction group modeled confounded and unconfounded experiments for the students. They also asked students to predict if the design would tell them if a variable had an effect on the outcome. Then the direct instruction teachers explained how the unconfounded experiments showed what factor caused the result because it only tested one variable at a time. Likewise, the teacher explained how the confounded experiments did not identify the changing factor because more than one variable was changed. The students in the discovery-learning group continued hands-on investigating of constructing their own experiments with the same variable focus as the direct instruction group. However, the discovery group received no teacher instruction or feedback. During the baseline and assessment phase of the ramp exploration students were asked to design four experiments and therefore, could obtain a score from 0 to 4. The assessment took place the same day as the instruction. Both groups of students were asked to create two experiments that showed how the ramp's steepness affects how far the ball rolls and two that showed how the ramp's surface area affects how far the ball rolls. The second lesson, which took place a week later, students from both groups were asked to evaluate two imperfect science fair posters individually. The posters showcased other students' investigations and included (a) the research question, (b) a description of the hypothesis, (c) the procedure, (d) materials, (e) results, and (f) conclusions. After the experimenter read the poster to each child, each child was asked to generally and specifically critique each element of the poster. The students' answers were transcribed and coded. Their score was calculated from the total number of correct critiques over any aspect of the poster. Findings revealed that both direct instruction and discovery learning students increased from baseline to final experiment but the direct instruction students' gains were more dramatic. In the direct instruction group 40 out of 52 students were able to design three out of four experiments while only 12 out of 52 discovery students were able to (Klahr and Nigam, 2004, p. 665). A common stated disadvantage to direct instruction is that students taught through direct instruction are sometimes thought to be unable to transfer new knowledge to authentic tasks as effectively as students who are taught through inquiry-based instruction. Therefore, Klahr and Nigam found the results of this study promising because there was no difference between student's abilities to transfer knowledge to the poster task, no matter how they were taught. Klahr and Nigam (2004) conclude:

> The most important result of this study is the relationship between learning paths and transfer. Children who became masters via direct instruction were as skilled at evaluating science-fair posters as were discovery-learning masters and experts. Similarly, children who failed to become masters did equally poorly on poster-evaluation task regardless of training condition (Klahr and Nigam, 2004, p. 666).

One of the major limitations of this study is the author's depiction of what inquiry-based or "discovery" learning looks like. Teachers rarely implement inquiry-based instruction where their role is nonexistent. The teacher is still involved—guiding and facilitating student learning through prompts, feedback, questions, and specific experiment designs. For this study, what was called "discovery learning" was not the same thing as inquiry-based instruction because the students were simply allowed to continue to play with the ramp to create their own experiments. Due to this more research needs to be done comparing direct instruction and inquiry-based instruction where the teacher facilitates student learning.

A study by Dejonckheere, De Wit, Van de Keere, and Vervaet (2016) in Belgium also looked at the effects inquiry-based instruction had on control of variables. Unlike the study by Klahr and Nigan (2004), however, in this study the teacher actively facilitated the learning. Two schools were selected randomly to participate in the study. From the schools two classrooms were assigned to the intervention group and two were assigned to the control group. The intervention group consisted of one class of 4/5-year-old students and one class of 5/6-year-old students. The teacher implemented 15 inquiry-based activities that covered topics such as sinking and floating, magnets, keys and locks, and dropping objects over seven consecutive weeks. In each session two to four activities were presented at the same time, which allowed all activities to be selected at least twice. Each lesson contained three phases: intro phase, explore phase, and a trigger phase. During the intro phase the teacher showed the materials, had the students make connections to the content, and showed what students could do with the materials during explore time when they were placed at the science counter. No specific instructions were given to the students. In small groups students freely played with the materials during explore time for a maximum of 40 minutes. During the trigger phase the teacher asked pre-determined probing questions that focused the students' exploration toward cause and effect (Dejonckheere et al., 2016, p. 545-546). The control group which consisted of one 4/5-year old class and one 5/6-year old class had normal classroom routines. Students participated in the same pre and post assessment in a separate room with an experimenter where they were shown a light box and block. The child watched as the experimenter placed the block on the box and off the box. The second time the experimenter placed the block on the box, the box lit up until the experimenter removed the block. The experimenter then prompted the student to experiment with it by asking them how the light turns on. For 75 seconds the experimenter observed the child playing; looking for informative actions of only testing one variable at a time (Dejonckheere et al., 2016). The analysis of the students' pre and post experiments with the light box showed that children from the intervention group who participated in hands-on classroom investigations generated more informative explorations and fewer uninformative explorations. Findings also showed that students who received the hands-on investigations explored more with the block's orientation, shifted its position, and other variables than the control group. The control group demonstrated more uninformative explorations and fewer informative explorations in the post-test. The researchers concluded that early exposure to reasoning, predictions, hypothesis, and problem solving through guided play could support a child's critical thinking skills and scientific reasoning (Dejonckheere et al., 2016). A limitation of this study was its small size. It is also hard to determine what factor directly affected the outcome, that is, whether it was the teacher's questioning, exploring with peers, teacher modeling, or a combination. More research needs to be done to see which variables affected the student outcomes.

Varelas et al. (2008) conducted a study of 27 second graders and 20 third graders to see the influence inquiry-based instructional practices had on students' understanding of classifying solids, liquids, and gases. The classes were from two urban public schools in the Midwest. The second grade class had 12 Latinos, 3 African Americans, 11 European-Americans, and 1 Asian American. Spanish was the primary language for five of the students and 60 percent of students lived in poverty. The third grade class had 20 African Americans that looped with their teacher from the year before. Ninety-eight percent of students in their school were at poverty level. The teacher anchored the lesson in text using the read aloud: *What Is the World Made Of? All About Solids, Liquids, and Gases* (Zoehfeld, 1998) to define the three states of matter and their properties. Next the students participated in hands-on group investigations. Students were asked to sort several everyday objects into categories based on the three states of matter and record their decision with an explanation. The teacher purposely chose the following objects: (a) a bottle with liquid soap, (b) a bar of soap, (c) shaving cream in a baggie, (d) a can of chicken noodle soup, (e) a pencil, (f) a drinking straw, (g) a helium balloon, (h) a non-inflated balloon, (i) a piece of clay, (j) a sponge, (k) salt in a baggie, (l) a baggie puffed up with air, (m) a bottle of water, (n) a piece of string, (o) a tube of paint, and (p) a rubber band because she believed they would promote student disagreements and encourage justifications in student discourse (Varelas et al., 2008, p. 72). Students participated in small group discussions during the hands-on exploration and as a whole class to summarize their classifications. Researchers analyzed field notes, transcripts of videotaped classroom discourse, students' written work, and pictures of class artifacts for different ways children sorted the states of matter and how the children and teacher interacted during discussions. Findings suggest that the hands-on activity allowed students to manipulate objects in new ways that promoted new ideas. It also promoted debate and student explanations guided by the teacher. Four themes of children's reasoning for classifying emerged: (a) macroscopic properties: it kept its shape, (b) prototypical reasoning: it is made out of plastic therefore, it is solid, (c) functional reasoning: you write with a pencil so it is a solid, and (d) process of elimination (Varelas et al., 2008). Within the investigations children challenged others' ideas and also acted as mediators. The students' ability to hold and squeeze the different materials helped them see and understand different characteristics of each object, which helped them determine its state of matter and sparked extensive discussions (Varelas et al., 2008). For example, one student noticed the salt felt hard so she determined it was a solid and another student poured the baggy of salt and noticed it did not keep its shape, so it could not be a solid. A limitation of this research is the observer was in the classroom all year because this study's data was collected from one unit of a larger study. The observer might have affected how the teacher taught or impacted or guided how the student discussions went.

These studies show the importance of teacher facilitation with the use of hands-on investigations and how those investigations allow students to explore science phenomena. Simply letting students "play" or explore with materials or kits will not guarantee the student success (Slavin et al., 2014). Minner et al. (2010) found in their research synthesis "...hands-on activities alone were not sufficient for conceptual change. Students also needed an opportunity to process for meaning through class discussion of the reasons behind what they observed in their independent design activities" (p.491). The next section explores how teachers can help facilitate hands-on investigations through discourse.

The Role of Discourse in Inquiry

An important element of inquiry skills is reasoning. Students need to use evidence to make claims and critique the claims of others. Discourse is a powerful tool that allows students to communicate their ideas, challenge other students' ideas, and make connections within concepts or content.

Siry, Ziegler, and Max's (2012) qualitative study investigated how discourse helps children make meaning of science phenomena. The study took place in Luxembourg with 29 four to six year olds. Students explored water through manipulation of water tubs and containers the teacher set out. The teacher moved from group to group prompting with one question: which container has the most water? The researchers analyzed video and audio of 45 days of science activities, kids' photos, writings, and paintings looking for themes. Data showed that students' discourse about science emerged during hands-on exploration. Three main themes appeared:

1. Science investigating starts to develop when teachers give students an activity with a specific goal. Through their actions in the activity, science discourse will naturally emerge between the students.
2. Students will use gestures, everyday language, and scientific language to participate in science discourse.
3. Through science investigations and discussion, students show an understanding of science content. Their discussions transition from observations about what they are doing to explanations of science concepts and science learning (Siry et al., 2012, p. 320)

This study suggests that young children are able to participate in quality discourse on scientific processes and concepts through the use of gestures and actions within collaborative investigations (Siry et al., 2012). A limitation from this study is the limited knowledge we have about the student demographics. More research needs to be done on discourse with diverse students to see if certain students dominate discussions and ideas. Further research is needed on the relationship between discourse and students' science knowledge and outcomes. Researchers could also examine which type of discourse: peer discourse or teacher facilitated discourse is more effective for students.

Jurow and Creighton's (2005) study of two K-1 teachers in an elementary laboratory school on the west coast looked at how they used improvisational science discourse to increase students' participation in their learning and deepen students understanding. Improvisational teaching uses students' on the spot ideas and interests to adjust teachers' instruction so that the students have a deeper understanding of the content and can master the curricular goals. It happens in the middle of teaching and is not scripted ahead of time. This type of discourse aligns with inquiry-based instruction, where the learner plays an active role in their learning. It differs from teacher driven discourse that is teacher centered and fact driven (Jurow and Creighton, 2005). The two classes met at least once a week for science instruction. This instruction consisted of whole group discussions, demonstrations, small group activities, and hands-on explorations. Field notes, student work samples, and videotapes of 20 science lessons were analyzed for verbal and nonverbal student interactions. Teachers were also interviewed on the goals of each lesson and their instruction method. The researchers collected and analyzed data on the interactions between the teacher's support and student participation. They looked specifically at how those two things progressed mutually over time (Jurow and Creighton, 2005). A pattern was coded as improvisational discourse when a teacher took a student's unexpected idea and built/shifted instruction off it (Jurow and Creighton, 2005). Findings showed this happened 11 times in 20 science lessons. Two major themes emerged that showcase how to use improvisational discourse to increase students' participation and scientific thinking. The first theme was that the teachers often told students they were going to be a certain type of scientist. That way the students knew what their part was in the lesson. The teachers modeled how to act like a scientist, gave resources to help the students act like a scientist, and named what it would look like to be that type of scientist. This helped the teachers present their expectations to the students so they knew how to participate in the lesson. The second theme was that the teacher would expand on students' ideas and tie it back to the science practice or process being studied. This showed the students that there are many ways to make sense of science. It allowed students to deepen their understanding by taking personal experiences and connecting them to new scientific knowledge. In conclusion, the researchers state:

> ...students can learn to use science as a tool for thinking when they are encouraged to explore ideas and improvise. Furthermore, while students at the K-1 level are often underestimated in terms of their abilities to develop sophisticated scientific understandings, this analysis demonstrates that young students have insights about science that, if recognized and appreciated by their teachers, can be used to help them develop more complex understandings of scientific content (Jurow and Creighton, 2005, p. 293).

A limitation in this study is the fact that teachers in the lab school had a great deal of flexibility with their curriculum. This type of student-led discourse instruction may be harder to implement in a school where teachers are not given as much curricular freedom. The teachers at this school were also able to team-teach science. If teachers were not allowed to team-teach, facilitating discourse may be more difficult and less productive. Another limitation of this study is the fact that all of the learning outcomes are descriptive because it is a qualitative study. This makes it hard to compare the learning outcomes of this approach to other approaches. Further research needs to be done on improvisational discourse in public schools and more studies to see if the pattern continues and how it affects students' science outcomes.

Papandreou and Terzi (2011) conducted a qualitative study of eleven 5-6-year olds and five 4-5 year olds in Western Macedonia to determine how different discussion formats can promote exploration of kindergarten students' ideas about the Earth. The exploration of ideas lasted three days and included six activities that covered material on the Earth's shape and the day/night cycle.

The activities included:

1. Narration of short story followed by whole group discussion led by a doll asking questions about the Earth.
2. Students producing drawings of the Earth during the day and at night.
3. A personal interview between the student and teacher.
4. Whole group discussions over particular drawings the teacher chose based on different characteristics.
5. A game where the students chose a 3D shape that resembles the Earth. Then they compared these to the drawings, and had a discussion about where people live.
6. Whole group discussion on drawing characteristics of Earth in the day and Earth at night. (Papandreou and Terzi, 2011, p. 33)

Data sources included tape recordings, field notes, children's drawings, personal interviews, and transcribed group discussions. The findings showed the drawings and discourse supported each other to enhance explanations. That is, the drawings helped facilitate more discussion and the discussion gave more clarification to details in the drawings (Papandreou and Terzi, 2011). Many students also used body language to clarify their thinking. Many themes emerged from the group discussion that showcased the students' communication skills and understandings or misconceptions about the Earth and day/night cycle. Students discussed the Earth's characteristics and sources they got the information from. Within the discussion students added on to other students' ideas or disagreed with previous students' comments. Listening to other students' ideas also sparked some students to share new information that they had not in any of the prior activities. Some children talked for the first time in the sixth discussion. After seeing how the variety of discussion activities in this study allowed all students to express their ideas and how the varying of material with the shapes and drawings helped elicit a wide variety of students' ideas, the authors suggest that using different modes and materials to have students communicate their understandings may help prompt new ideas and improve class discourse. One limitation of this study was its small size; continued research should be done with larger populations. Another limitation is that it was done with one specific science concept that is very abstract. Students cannot directly observe the shape of the Earth and therefore, would have to take their teacher's word. This calls into question whether they really gained understanding or mere compliance. Additional research covering other science concepts that students are able to observe themselves is important to determine if students would produce as much discourse, ideas, and understanding.

Decristan et al. (2015) conducted a study of 1,070 third graders from 39 German public primary schools to look at the influence different types of additional guidance with inquiry-based instruction has on student conceptual understanding. The authors were particularly interested in the benefits it might have for low language learners. Each school was randomly assigned to the control group or one of three guided experiment groups:

scaffolding instructional discourse (SID), formative assessment (FA), or peer-assisted learning (PAL). All four groups taught the same inquiry-based science unit on sinking and floating, however the other three groups added a guided element: SID, FA, or PAL. The teachers had four days of professional development over sinking and floating content and their teaching approach. All teachers taught one 45-minute lesson and four 90-minute lessons. All teachers were given the same materials for hands-on investigations and a detailed manual. The teachers in the SID intervention had additional materials that included prompt cards to support their discourse and student prompt cards to help complete tasks. Teachers in the FA intervention were given four additional formal embedded assessments and shown how to give specific feedback on them. They were also expected to adjust tasks based off data from the assessments. Teachers in the PAL intervention were shown how to create student partners based on their conceptual understanding and how to manage student conflict. Their materials were slightly different because they included information about how to help partners change roles. Students were given a pre-and post-assessment to measure their conceptual understanding of sinking and floating. The assessments consisted of multiple-choice items and two free-response questions. The researchers analyzed the assessments using a 0-3 score; 0 representing a naïve conception, 1 representing everyday life conceptions, and 2 representing scientific conceptions (Decristan et al., 2015). Not all of the questions on the pre and post assessment were the same so the analysis only included the 7 common questions to both. Analysis of the pre-and posttest scores showed that students' conceptual understanding increased in all four interventions. The researchers had hypothesized that students that received additional guidance would increase their mean conceptual understanding more than students who received inquiry lessons without guidance. Contrary to this prediction the results actually showed only the FA classes scored significantly higher on the post assessment than the control group. Results from the PAL and SID groups were not significantly different from the control group. The researchers did a multilevel regression analysis to examine the relationship between language proficiency and conceptual knowledge within each intervention. The results showed the SID and FA interventions provided more support to students with poor language proficiency than the control group (Decristan et al., 2015). This study suggests that embedding formative assessment when implementing inquiry instruction can help students achieve science outcomes and that providing additional guidance is not necessarily needed to help students improve their conceptual understanding if teachers create quality inquiry-based lessons. One limitation of this study is what effects the teacher quality and attitude had on the delivery of instruction. The authors believed the teachers in the SID and PAL groups had a harder time implementing their methods and may have needed additional PD than what was given to each group. The authors did not address whether some of the strategies used in the different treatment groups might have also been used in the control group.

Sometimes inquiry-based investigations can be messy with students trying and failing repeatedly until they come to the correct conclusion. Decristan et al. (2015) explained how discourse is an important tool teachers can use to help support and guide students with poor language proficiency throughout the inquiry process because it provides scaffolds that include linguistic facilitation. Through discourse the teacher scaffolds the discussion with prompts, questions, and sentence starters to help increase the use of vocabulary, help students articulate their thoughts, and guide students to make connections to the content, which can increase understanding. The studies reviewed in this section demonstrate how teachers can use discourse to obtain students' misconceptions and guide the construction of science understanding through students sharing and building off each other's ideas (Papandreou & Terzi, 2011; Siry, Ziegler, & Max, 2012). Discourse is not only an important strategy to use for inquiry science but it can also be used in reading and math.

The Role of Literacy in Inquiry

Many teachers understand the benefits of teaching science but cannot find time in their day to implement it. Often this is because of the pressures from principals and school districts to make reading and math a priority to ensure students will perform on achievement tests such as FAST and MAPS. The following studies look at how teachers can combine literacy and science to alleviate this problem and help students succeed in both domains.

Cervetti, Barber, Dorph, Pearson, & Goldschmidt (2012) conducted a study with fourth graders in 16 school districts in urban, suburban, and rural communities to see how an integrated approach to science-literacy compares to business-as-usual approaches on students' science understanding, reading comprehension, science vocabulary, and science writing outcomes. Teachers in the treatment group taught 10 lessons on light that were 45-60 minutes long. Four lessons focused on hands-on investigating, two focused on reading information texts on the content, two focused on writing, and two focused on discourse. The teachers integrated reading strategies such as making predictions, determining the main idea, using evidence to back claims, and goal setting into science instruction. They received no professional development but instead were given materials and a manual with explicit instructions. The control groups taught the light unit like they usually do to meet their state science standards. The time spent on it matched the treatment group. Pre-post multiple-choice tests were used to measure science understanding of light and reading comprehension. A pre-post definition matching was given to assess vocabulary and a pre/post writing assessment was given. To analyze the students' scores the researchers used a three-level random effects model that divided the variation of student learning into between-student, between-teacher, and error components (Cervetti et al., 2012, p. 643). The researchers found post-test scores were higher for both groups compared to pre-test scores. They also found no difference between the groups for reading comprehension. However, the treatment group scored significantly higher in science vocabulary, science understanding, and in all categories on the writing rubric except vocabulary definition and conclusion compared to the control (Cervetti et al., 2012). Students in the intervention group not only developed more conceptual vocabulary and big ideas about light but they also integrated those ideas into their writing (Cervetti et al., 2012). The researchers suggest teachers should integrate language and literacy strategies and skills into inquiry-based science lessons. These strategies will not only support the effectiveness of hands-on investigations but the authors suggest they may also support student outcomes in reading and science (Cervetti et al., 2012). This research has the potential to assist teachers who have a difficult time finding time to fit science in their schedules while also meeting all of the literacy demands of their school district. By integrating literacy strategies into inquiry-based lessons they can focus on multiple areas at once. Teachers will have more time to develop quality science lessons, rather than fitting in quick hands-on activities or no science at all. One limitation of this study is the limited information on the comparison groups' instruction and their varied instruction methods because they were made up of numerous school districts across the state. This study was also done with older students so more research would need to be done to see how effective it is with younger students.

One study that looked at the effect science and literacy integration could have on primary students' reading and science outcomes was done by Vitale and Romance (2012). Vitale and Romance used an adapted version of Science IDEAS (Romance & Vitale, 2012; Vitale & Romance, 2006) with 363 first and second graders in two Florida elementary schools to determine its effect on their science knowledge and reading comprehension. Science IDEAS, allows teachers to incorporate many reading and writing strategies and skills into hands-on inquiry investigations that will deepen students' knowledge and understanding of science concepts (Vitale & Romance, 2012). The four participating schools were selected from a larger group of elementary schools that were already implementing Science IDEAS for grades 3-5 because the student demographics were similar and it ensured that the science teaching support within each school was similar. Both the control group and the intervention group taught the same reading/language arts program. Each of the two schools were randomly assigned to the 1-

2 Science IDEAS intervention or control group. The intervention group received 45-minute lessons daily from the classroom teacher that focused on core science concepts integrated with reading and writing activities. The literacy instruction received in the intervention group was in addition to the regular reading and language arts instruction the students received. The teachers used read-alouds, journaling, simple concept mapping, hands-on activities, and group discussions throughout the lessons. They had two days of professional development at the beginning of the year and two and a half more throughout the year. The teachers in the control classrooms taught the regular district science programs. Both the control and intervention group used the same basal reading program to teach reading and language arts and had age appropriate hands on materials. The researchers used the Iowa Test of Basic Skills reading comprehension and science subtests for grade one and grade two to measure results. Findings showed that the intervention groups had statistically significant gains in reading and science on the ITBS compared to the control groups. The researchers concluded, "Obtaining this dual achievement outcome, the impact of age-appropriate, in-depth integrated science instruction on reading comprehension justifies the increased time allocated for daily science instruction" (Vitale & Romance, 2012, p. 467). One limitation to note is that the researchers originally conducted the study for eight weeks and had mixed results so they extended it to a year. Further research should be done to show these results are consistently replicated.

A study conducted by Shepardson and Britsch (2001) looked at the impact of journal writing on students' science understanding during inquiry-based lessons. The case study took place in the Midwest with 18 kindergarten students and 20 fourth grade students. The students were middle to upper class. The kindergarten students conducted a three-day investigation on dissolving. They had group discussions about dissolving and conducted investigations with different material to see if the material would dissolve in water. The teacher gave the students a data table to put in their journals to summarize their results. On the second page of their journals they wrote about what they learned. The teacher's goal was for the students to use the science journal to showcase their science understanding of the investigations and incorporate new language into their writing. (Shepardson & Britsch, 2001). The fourth graders investigated sound by exploring pitch and conducting rubber band experiments. The teacher had the students use their journals to record their prior knowledge on sound, make predictions, and record their small group investigation. Data from video and audio of the small group lessons, photocopied student journals, informal teacher interviews, and field notes were analyzed. Findings showed two themes. The first theme that emerged was the different ways students expressed what they learned from the science investigations. The researchers found the students explained their ideas using (a) imagination or stories, (b) personal experiences, or (c) recounted the actual science investigation (Shepardson & Britsch, 2001, p. 51). When analyzing the kindergarten students' journals they often saw children use more imagination. For example, after experimenting to see if dirt dissolved a kindergarten student drew a duck on her journal page and explained to the researcher about how the duck didn't like walking on the dirt because it mixes up with the sand and is dissolving, even though the experiment did not involve ducks (Shepardson & Britsch, 2001, p. 53). The students tested both dirt and sand but the child explained the information in her journal in an imaginative setting with the duck story. Analysis from the fourth grade journals tended to show factual representation of the science investigation. All of the fourth graders used a combination of writing and drawing in their predictions and reasoning. Half of the fourth grade students used a data table to organize their ideas from the investigation (Shepardson & Britsch, 2001). The second theme that emerged was how the students used their experiences with different types of texts to represent their own ideas about their science investigations in their journals. Some students used elements taken from narratives and other students used nonfiction text structures from their science books (Shepardson & Britsch, 2001, p. 62). One kindergarten student incorporated elements found in nonfiction text such as key terms, definitions, and arrows. However, a lot of kindergarten students mimicked narrative elements to tell a story in their journals (Shepardson & Britsch, 2001). Most of the fourth grade students mimicked science texts with science language, data tables, and explaining patterns they noticed. Some fourth grade students used webs to organize their thinking about the investigation which is a tool typically seen with fiction text. The researchers conclude that the use of journals in inquiry science has many benefits: it allows the teacher to see what students understand of the science content, and the journals promote social and cognitive development, and encourage discourse (Shepardson & Britsch, 2001). A limitation of this study was the small number of students and that the students were of a higher SES. Additional studies will need to be done and with more diverse populations to see if using a journal in inquiry lessons can produce similar results.

Summary

This chapter reviewed several studies that showed the academic benefits of inquiry-based science instruction. Inquiry-based science instruction allowed students to learn and explain more difficult science content (Van Hook, Huziak, & Nowak, 2005, Varma, 2013, and Van Hook & Huziak-Clark, 2008). Several studies from this chapter also showed that inquiry-based instruction produced mixed results or negative results on students' learning outcomes. Having students explore science content through kits, use hands-on materials, or conduct CVS investigations independently is not enough to affect student outcomes (Slavin et al., 2014; Minner et al., 2010; Klahr & Nigam, 2004). One possible explanation for the finding that many of these studies showed mixed benefits or negative benefits for students is because the inquiry-based instruction within the study did not actually contain all of the components needed to be considered effective inquiry instruction. Klahr & Nigam's (2004) study, for example, depicted inquiry-based instruction as mere discovery learning where students used materials for trial and error learning with no teacher support to help them analyze data or communicate with others about the outcomes they witnessed. Many of the studies used in Minner et al. (2010) synthesis did not give detailed explanations on the methodology of how the inquiry instruction was implemented or what it looked like. So many of the studies may not have actually used inquiry-based instruction. Another major element that could have affected the results was teacher implementation and the amount of support they had. Inquiry-based instruction has many elements, and without proper training through on-going professional development, it can be difficult to implement solely from materials. Many of the teachers in these studies were only given curriculum to follow and materials or had limited amounts of professional development.

This review also looked at how teachers implement inquiry-based science instruction in the classroom through teacher-led discourse or student discourse, hands-on learning facilitated by the teacher, and through an integration of literacy and science where the student is using writing and informational texts to learn science or assess what they know (Shepardson & Britsch, 2001; Vitale & Romance, 2012; Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012). Many of these studies showed that science can be infused with the reading, writing, speaking, and listening skills teachers are already teaching. The studies also highlighted the important role the teacher has as a facilitator within the inquiry process through discourse, embedding cross-curricular strategies, and designing investigations and choosing hands-on materials that will scaffold student learning to get them to the next level of understanding. Simply giving students hands on materials and letting them explore is not inquiry-based instruction.

Chapter III

Conclusions and Recommendations

I chose the topic of inquiry-based science instruction for this review of literature because I enjoy teaching science and I want to create experiences for my students that will spark their love and excitement toward science too. My research review examined the benefits of inquiry-based instruction because I want to learn effective strategies to help my students have a deeper understanding of science concepts. I also specifically researched how teachers implement inquiry into their teaching to give me ideas of ways to effectively implement science that would allow my students to master the new NGSS.

Inquiry-based science instruction allows students to invest in their own learning by asking questions and creating or exploring investigations to solve their questions about science phenomena. Through this process students are able to improve their inquiry skills, justify their ideas, and create a deeper understanding of science concepts. Patrick, Mantizicopoulous, & Samarapungavan's (2009) study and Aydeniz et al.'s (2012) study shows inquiry-based instruction is motivating for students and can change their attitude toward science. Many of the studies showed that through inquiry-based instruction students could develop an understanding of key science concepts such as thermodynamics, energy, simple electric circuits, and air. After participating in inquiry lessons the students were also able to use more vocabulary and reasoning in their explanations of these topics (Van Hook & Huziak-Clark, 2008; Varma, 2013; Van Hook, Huziak, and Nowak, 2005; Aydeniz et al., 2012). For inquiry-based instruction to be effective for students, teachers need to be given ongoing and individualized on-site coaching and professional development on how to facilitate and support the students (Slavin, Lake, Hanley, & Thurston, 2014; Cotabish, Dailey, Robinson, & Hughes, 2014). Simply letting students explore investigations or explore with kits on their own will not guarantee student success (Slavin et al., 2014; Klahr & Nigam, 2004).

In this chapter I draw on results from the research articles to suggest recommendations for teachers, principals, and instructional coaches. The recommendations in the first section are based on the research results on academic benefits of inquiry-based instruction. The recommendations in the second section are based on the results on how teachers implement inquiry-based instruction.

Insights and Recommendations on the Academic Benefits of Inquiry

In this section I highlight key ideas supported by results from the research articles on the benefits of inquiry-based instructions. It specifically addresses insights and recommendations on: inquiry process skills, reasoning skills, and literacy and science outcomes.

Science Process Skills

The findings demonstrating a positive relationship between inquiry-based instruction and students' science process skills (what the NGSS K-12 Framework calls *Scientific and Engineering Practices*) suggests inquiry-based instruction is a method to help students' increase their science process skills such as asking questions, making predictions, recording observations, developing investigations, analyzing data, and sharing findings (Varma, 2014; Van Hook & Huziak-Clark, 2008; Dejonckheere, De Wit, Van de Keere, & Vervaet, 2016; Jurow & Creighton, 2005; Van Hook, Huziak, & Nowak, 2005; Samarapungavan & Mantzicopoulos, 2011; Cotabish, Dailey, Robinson, & Hughes, 2013; Siry, Ziegler, & Max, 2012; Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Vitale & Romance, 2015). This recommendation is further supported by the research showing students in control groups that received regular science instruction scored lower on science process questions than students who received inquiry-based instruction (Samarapungavan & Mantzicopoulos, 2011; Cotabish, Dailey, Robinson, & Hughes, 2013). Results from several of the research studies also show a positive relationship between inquiry-based instruction and students' understanding of complex science concepts. Students demonstrated a deeper understanding of thermodynamics, energy, and air through inquiry-based science instruction (Van Hook & Huziak-Clark, 2008; Van Hook, Huziak, & Nowak, 2005; Varma, 2014). Based on these findings, I recommend teachers:

1. Do not simplify or limit science curriculum for lower elementary students
2. Create inquiry-based lessons that involve multiple aspects of the inquiry process.

Reasoning Skills

The findings demonstrating a positive relationship between inquiry-based instruction and student reasoning skills suggests inquiry-based instruction should be used to promote student explanations and justification of their ideas (Van Hook & Huziak-Clark, 2008; Van Hook, Huziak, & Nowak, 2005; Siry, Ziegler, & Max, 2012; Varelas et al., 2008; Papandreou & Terzi, 2011; Shepardson & Britsch, 2001). Using inquiry-based instruction to promote student explanations is further supported by the research that shows children incorporate more vocabulary terms into explanations after inquiry-based instruction (Van Hook, Huziak, & Nowak, 2005). Based on these findings, I recommend teachers:

1. Have students use a science journal to make predictions, summarize learning, or state a claim where they have to explain their thinking.
2. Use sentence stems for students that emphasize reasoning in whole group discussions and in small group work such as "I think ______ because…."

3. Create assessments that include (a) short answer, (b) essay, or (c) projects and presentations where students have to justify their ideas.

Literacy and Science Outcomes

Important findings from Vitale & Romance's (2012) research that demonstrates a positive relationship between the integration of literacy and science and students' reading and science outcomes on ITBS suggests literacy and science strategies should be integrated in inquiry-based lessons to promote cross-curricular skills and student outcomes. This recommendation is further supported by the research showing a positive relationship between use of evidence, introduction, clarity, science content, and increased amount of science vocabulary in student's writing when those student experienced inquiry-based science and literacy integration (Cervetti, Barber, Dorph, Pearson, Goldschmidt, 2012). In addition, several studies that incorporated literacy elements into inquiry instruction such as journal writing and nonfiction read alouds showed positive student science outcomes and understanding (Cervetti, Barber, Dorph, Pearson, Goldschmidt, 2012; Shepardson & Britsch, 2001; Zhang, Eberhardt, & Passalacqua, 2011; Slavin, Lake, Hanley, & Thurston, 2014; Varelas et al., 2008). These results are important because time is one of the major reasons many teachers do not teach science or use effective strategies for science implementation. Based on these findings, I recommend teachers:

1. Incorporate nonfiction read alouds into reading instruction and science instruction and ensure access to a variety of nonfiction informational books.

2. Create read alouds where teachers model identifying text features and text structures of nonfiction text that help students understand the data presented and understand the author's purpose for using it.

3. Encourage students to mimic text features and structures in their science journals when making predictions, detailing an investigation, presenting results, or analyzing results.

4. Have students write to learn through journaling, writing prompts, or quick writes where they are explaining their ideas.

5. Have students work on their speaking and listening skills by incorporating think-pair-share, small group work, and whole group discussions.

6. Incorporate reading strategies such as making predictions, asking questions, and monitoring understanding in science instruction.

I recommend principals:

1. Provide teachers with quality nonfiction texts and resources.

2. Encourage teachers to create units that combine their reading and science standards through the use of professional development and instructional coach support.

3. Allow teachers to have a flexible schedule so they have the ability to incorporate students' interests into curriculum and adjust lessons based on students' ideas or remarks.

Insights and Recommendations for Inquiry Implementation

In this section I highlight key ideas supported by research articles on how teachers implement inquiry-based instruction. This section specifically addresses insights and recommendations on: professional development, teacher facilitation, and discourse.

Professional Development

The findings from Slavin et al.'s (2014) research synthesis that show a positive relationship between inquiry programs with extensive professional development and student science outcomes suggest teachers need professional development on how to design, implement, and facilitate inquiry-based science lessons. This recommendation is further supported by several of the inquiry studies in this review that had positive student outcomes from programs that had teachers participate in professional development prior to the study, during the study, or both (Vitale & Romance, 2015; Zhang, Parker, Eberhart, & Passalacqua, 2011; Cotabish, Dailey, Robinson, & Hughes, 2013). A few studies that provided teacher support through the use of peer coaches also demonstrated student success (Cotabish, Dailey, Robinson, & Hughes, 2013; Samarapungavan & Mantzicopoulos, 2011). Based on these findings, I recommend principals:

1. Provide funding for professional development where teachers receive coaching and form professional learning communities to develop experience with inquiry-based lessons.
2. Provide teachers with resources that demonstrate examples of inquiry-based lessons that match NGSS from varying grade levels.
3. Allocate time for professional development that models good facilitating strategies and allows work time where teachers can collaborate to design effective questions that will promote higher order learning and scaffold students' work as they investigate science phenomena.
4. Provide teachers access to science experts who can help them create a checklist or rubric to critique the effectiveness of their lesson and inquiry components.

5. Promote the importance of science and require teachers to include it in their daily schedules.

6. Provide teachers with instructional coaches for support with planning and implementing inquiry-based lessons.

I recommend teachers:

1. Form collaboration groups to help brainstorm ideas and create inquiry-based lessons.

2. Continually reflect on best practice to decipher if students are mastering NGSS and if the lesson is truly inquiry-based.

3. Provide principals and district leadership teams with feedback on what resources and strategies they need more help on to improve their inquiry-lessons as they implement.

Teacher Facilitation

The findings from Dejonckheere et al.'s (2016) study that demonstrate a positive relationship between students' ability to test for control of variables in investigations and teacher-facilitated inquiry-instruction suggests teachers need to facilitate student learning during inquiry-based lessons through prompting, discourse, questions, and feedback. This recommendation is further supported by the research from Klahr & Nigam (2004) that showed students who received inquiry-instruction but received no teacher support demonstrated much lower gains than peers who had direct instruction. While Klahr & Nigam used these results to show direct-instruction was superior to inquiry-based instruction for teaching science concepts, I believe they did not actually compare the two methods. In their study the teacher's role was nonexistent for the inquiry-based instruction group and teacher facilitation is a vital element of inquiry-based instruction for young children. Other studies such as Siry, Ziegler, & Max (2012) and Siry and Max's (2010) crayon investigation also show how the teacher's facilitation throughout the inquiry investigation helped guide the students toward the expected science concepts, which enabled the students to develop the targeted science understanding. Based on these findings, I recommend teachers:

1. Be intentional about their role in instruction when mapping out their investigations by (a) finding materials that will create dialogue amongst the students and best help teach the science concept (b) identifying misconceptions students might have and (c) developing prompts and additional investigations that will help scaffold the student's thinking or clarify their misunderstanding.
2. Develop questions that will cause students to explain their thinking and collect observational data on student actions or responses as they are monitoring students' explorations. These ideas and student strategies can then be brought into discussion to deepen understanding and promote powerful discourse.
3. Video record certain lessons or discussions to reflect on their facilitation.
4. Watch other teachers facilitate science inquiry lessons to gain ideas.

I recommend instructional coaches:

1. Observe teachers' facilitation in action and provide feedback on their questioning and scaffolding.
2. Collaborate with teachers to create facilitating questions and prompts.

Discourse

During Varelas et al.'s (2008) study where the students had to determine if objects were solids, liquids, or gases the teacher facilitated the discourse in many ways to promote student reasoning. Some examples include asking children to think of reasons behind their choices, encouraging children who had differing answers to analyze others ideas, debate and clarify their ideas to each other, and presenting objects in new way to encourage new ideas and explanations from students. Varelas et al.'s study demonstrates a positive relationship between student discourse in inquiry-based instruction and inquiry skills such as critical thinking and reasoning. These findings suggest that discourse is an important component that should be included in inquiry-based instruction to promote student reasoning. Through discourse students are able to work together to co-create meaning and understanding of science ideas (Varelas et al., 2008; Jurow & Creighton, 2005; Papandreou & Terzi, 2011; Siry & Max, 2013; Siry, Ziegler, & Max, 2012). The importance of discourse is further supported by research showing discourse is an effective tool that reveals students' science understandings and misconceptions (Jurow & Creighton, 2005; Papandreou & Terzi, 2011; Siry & Max, 2013; Siry, Ziegler, & Max, 2012). Research has also shown discourse to allow teachers to use students' ideas or comments to adjust instruction in order to give clarity to the learning or make it more meaningful for the students (Jurow & Creighton, 2005). Based on these findings, I recommend teachers:

1. Learn how to incorporate student participation strategies such as agree/disagree, wait time, add on, rephrase, and repeat into class discussions.

2. Set up a classroom climate where students can agree and disagree with ideas, discuss routines and expectations at the beginning of the year, use an anchor chart to remind students about discussion rules and protocols throughout the year.

3. Emphasize the importance of students backing up claims with evidence during discussions.

4. Create questions ahead of time about the science concepts/content that will: (a) provoke different answers, (b) utilize students' critical thinking skills, (c) and bring out misconceptions about content or concepts.

Future Research

Future research is needed on inquiry-based lessons in lower elementary with larger populations because few research studies involved inquiry science and elementary students and of those studies, many included only a few classrooms. To gain a better understanding of the academic benefits and effects of inquiry-based teaching it is important that future researchers conduct studies where the control group is receiving instruction on the same topic but using a different method. Too often the current research on inquiry-based instruction compares inquiry students' scores to a control group that received no teaching on the content. In Varma's (2014) study the comparison group received no instruction on the science topic being assessed and never even saw the experiment room or materials. Many other of the studies in this review included little or no information on what the control group was taught and the amount of time spent on science was much less for many of the control groups (Cotabish, Dailey, Robinson, &

Hughes,2013; Patrick, Mantzicopoulos, & Samarapungavan, 2009; Samarapungavan, Patrick, & Mantzicopoulos, 2011).

Research on the teacher's role during discourse could clarify better ways for teachers to facilitate inquiry-based instruction. Specifically, researchers could look at how teachers can involve students in curriculum through discourse and what types of questions promote participation and student understanding. Research that examines correlations between professional development over inquiry-based instruction and student outcomes would help science consultants design professional development to support inquiry implementation for teachers. Survey data could also be collected from teachers on what type of professional development they found valuable in implementing the new NGSS. Time is a big factor that keeps many teachers from teaching science so I think additional research that examines K-5 classrooms that combine literacy and science instruction and student outcomes on standardized tests and classroom science and literacy benchmarks would be useful for educators.

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