Let There Be Light

Teaching Light to Second Grade Students Through Inquiry-Based Science

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Second Grade

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Description of Teaching Context:

This inquiry project was conducted in two self-contained second grade classrooms, room 20 and room 25, at Gray's Woods Elementary School in Port Matilda, Pennsylvania. We are Professional Development School (PDS) interns teaching for one full year in the State College Area School District. State College Area School District is a large district located in central Pennsylvania. There is one high school, two middle schools, and ten elementary schools, totaling 7,233 students during the 2006-2007 school year. This school district is well known for its ability to prepare students with the knowledge necessary to be successful both inside and outside the classroom.

In room 20 there are 14 boys and 11 girls. The age range within the classroom is 7-9 years old. There is one black male and one male with a Hawaiian and Philippine background. The rest of the students are Caucasian. There is a mentor and a paraprofessional in the room at all times. The students have very diverse learning needs including five children receiving Learning Support, one child with emotional needs, three children receiving occupational therapy support, one child in Title I reading, and several children receiving Learning Enrichment. The desks are arranged into 4 clustered groups with 6 desks in three groups and 7 desks in one group, allowing for conversation and collaboration amongst the students. The teacher and student resources (computers, literature, paper, manipulatives, etc.) are located around the perimeter of the classroom so that instruction remains student centered. The students are given many responsibilities and opportunities to explore ideas independently across all areas of the curriculum.

Students have a voice in the classroom as they participate actively in their learning. The mentor and intern act as a guide, helping students discover how to search for knowledge on their own.

Room 25 is comprised of 24 seven and eight year olds. There are 13 boys and 11 girls. Three students attend a Title I reading program, which helps them reach the benchmark in reading for second graders. One student is taken out of the classroom for speech and language assistance and another is currently being evaluated by the Speech Pathologist. One student receives Title I and IST support and is currently receiving a Multidisciplinary Evaluation (MDE) to see if there are any problems in different areas (mental, processing, etc.). Two students attend a Changing Families Group, both dealing with divorced parents and being separated from their mothers. Eight students leave the classroom for Learning Enrichment in math. The majority of the students meet or exceed expectations in reading and writing. There are 22 Caucasian students, one black male student, and one female student whose parents’ native country is India. There is one mentor and paraprofessional in the classroom at all times. The desks are arranged into 5 groups, 4 groups have 5 students and one group has 4 students. Similarly to room 20, the teacher and student resources (computers, literature, paper, manipulatives, etc.) are located around the perimeter of the classroom so that instruction remains student centered. The instructional environment is highly structured, where students know the expectations and consequences of misbehavior at all times.

As you can see, these two second-grade classrooms have more differences than similarities, which made this collaborative inquiry project an even bigger learning experience than we had anticipated.

Rationale:

Currently, the State College Area School District *Light and Sound Unit* for primary grades is written as a teacher directed unit. While teaching this unit, a problem that teachers found was that in previous years these hands-on teacher directed lessons did not allow students to learn the concepts conceptually. These teacher concerns provoked us to question how we could take the teacher's concerns into consideration while teaching the *Light Unit*. The mentor in room 20 expressed her concern about the light portion of the unit because it did not allow students to develop a deep conceptual understanding about light concepts, therefore, preventing students from retaining what they had learned. Also, during unit planning for the *Light and Sound Unit*, many teachers expressed dissatisfaction with the light lessons because the students did not grasp the light objectives. Specifically, they mentioned that the color of light lesson was the most difficult for students to grasp because students did not understand that light is made up of colors of the rainbow by looking at prisms. By taking an inquiry approach focusing on evidence and explanations, we hoped that our students would develop a deep understanding of light while addressing the key concepts and standards of the unit. In order to accomplish this, we took what we had learned about the importance of inquiry through the PDS program and used it to take a teacher directed unit and transform it into an inquiry-based unit.

"As pointed out in the *National Science Education Standards* (National Research Council, 1996), students who use inquiry to learn science engage in many of the same activities and thinking processes as scientists who are seeking to expand human knowledge of the natural world" (National Research Council, 2000). Unfortunately, teaching science directly does not allow students to experience what it truly means to be a scientist. In theory we learned that teaching science through inquiry is an effective way of teaching students science as they become actively engaged in the learning process; allowing conceptual understanding to take place. "When students understand they are able to do something with their knowledge. They can use it to guide inquiry and to interpret, explain and make sense of the world" (Carin, Bass & Contant, 2005). By approaching the *Light Unit* in a new manner, we wanted to help our students understand light concepts through their involvement in the design of experiments and lessons. We focused on the implementation and development of lessons that emphasized inquiry and student choice as the lessons came from the wonderings of our students, therefore increasing their level of interest, and in turn, their level of learning. The inquiry approach allows students to interact with the materials and concepts in a hands-on environment as they use their imagination and curiosity to bring science to life. "Although endowed with a great learning capacity, children 'don't learn simply by listening to someone talk or by reading a book. Students have to take an active role in their own learning'" (Carin, Bass & Contant, 2005).

Choosing to teach this unit using an inquiry approach allowed us to use what we have learned in our science methods course and bring it to life in our classrooms. The focus of our inquiry project was exactly how to do this. As a result of this inquiry project, we began to ask different types of questions. We became comfortable asking more open-ended questions that forced students to think critically and analyze concepts. For example, we learned to ask students, "What makes you say that?" "How do you know?" and "What is your evidence?" We allowed our students to discover answers to their questions on their own, with the direction and guidance we provided, across all areas of the curriculum. We also noticed that we have been encouraging students more often to find evidence to support their learnings, which allows students to make connections and therefore strengthen their understandings. During the lessons, students showed a deep understanding of light as we watched them take what they had learned during experiments and apply that to other science light lessons as well as in their everyday routines. In our future teaching, we both plan to use an inquiry-based approach to teach science, as well as other areas of the curriculum. With the positive responses we received from students and mentors throughout this unit, we feel that teaching science topics through inquiry is both exciting and beneficial for second grade students. This inquiry project has allowed us to gain the confidence and skills necessary to teach many science topics effectively through an inquiry-based curriculum.

Main Wondering:

How can we transform a teacher directed science unit on light into an inquiry-based light unit?

Sub Questions:

How can you teach light through inquiry and meet all of the necessary objectives while still exploring student wonderings that do not fit objectives?

To what extent will students be engaged in their learning if provided a voice in the content of the curriculum?

What are the pros and cons of team teaching and collaboration during an inquiry-based light unit?

How do students who struggle with reading and writing perform during inquiry-based science lessons?

Inquiry vs. Improvement Project

When starting this project, we were not sure if our students were going to understand our lessons and be able to retain the information. For each inquiry-based light lesson we taught, we were not exactly sure how they were going to turn out. Although we planned our lessons with an idea about how they were going to look, we knew that one comment from one of our students could change the entire direction of the lesson. To us, this project was similar to driving a car. However, throughout this project, instead of one of us controlling the steering wheel we had to share the wheel, and in turn, the control of which direction the car was going to go. We had to surrender some of the control we once had over our students and place it upon them. We became responsible for serving as a guide for our students by listening to their responses and focusing on some, more than others, in order to reach the concepts that needed to be addressed. One of our biggest fears jumping into this project was that we would not be able to meet the objectives and still teach through the students' wonderings. Also, we had to put the students first before thinking about this project because if the lessons were unsuccessful and students were not learning, we had to be prepared to change back to the teacher directed lesson plans for the best interest of our students. Both of us were nervous and anxious before teaching each lesson because the lessons were led by our students, which was something we were not used to. Our PDA said it best when she said, "For inquiry, you have to be prepared to be unprepared" (Begg, personal communication, February 19, 2007) and that is exactly what we had to do for this project.

Inquiry Plan Description:

- *Jan 9th-Met with Judi Kur, Marcia Heitzman and Candy Stahl*

In order to ensure that we were headed in the right direction with our inquiry project, we met with these inquiry experts to get some ideas for possible inquiry lessons. They gave us many examples of inquiry lessons that worked in their classrooms, and also those that did not work. For example, one lesson that they found very successful in teaching students about the color of light was the use of refracting glasses, which we later incorporated into one of our lessons. They also informed us that using glass prisms to determine the color of light had been ineffective and confusing for their first graders and therefore, we made sure to not use the glass prisms in our classrooms when teaching about the color of light.

In addition to their help with ideas for inquiry-based light lessons, they were also able to give us good advice about how to teach inquiry best. One of the main points they stressed during our meeting was that our lessons, as well as the outcomes in our classrooms, would more than likely be very different from one another depending on what wonderings our students expressed. Therefore, we left this meeting still a bit unsure of what our lessons would look like because we needed to wait and see what wonderings our students expressed. Steve, a physics teacher quoted in *Inquiry and the National Science Education Standards* said, "… moving toward inquiry-based teaching meant adopting a different role as a teacher" (National Research Council, 2000). After our meeting, we also realized that our role as a science teacher was about to change. However, we felt anxious and positive about our journey ahead (Heitzman & Kur, personal communication, January 9, 2007).

* While collaboratively writing all of our lessons throughout this unit, we based them upon the 5-E model of instruction in order to help our students develop the light concepts conceptually. For an explanation of the 5-E model of instruction, please refer to Evidence 1A on page 18.

- *Week of January 22nd- KLEW chart*

During this lesson, our students went on a shadow hunt around the classroom with flashlights trying to find as many different kinds of shadows as they could. We chose this as the first lesson because we wanted to get our students thinking about shadows and light, so that we could illicit thoughtful responses based upon prior knowledge during the completion of the “What we know about light” section of the KLEW chart. After the shadow hunt, we had a science talk to discuss and record what our students thought they knew about light as well as their wonderings.

- *Week of January 29th- “What makes a shadow?” lesson*

Groups of students were given bins with different objects such as a transparency sheet, sandwich bag, saran wrap, rubber band, paperclip, plastic bag, unifix cube, glove, and clear red disk. Within their groups, they had ten minutes to use flashlights to make shadows with the provided objects. While the students were experimenting, we approached all of the groups, asking them what they were noticing about where the shadows were, how they were making a shadow, what they needed to make a shadow and what objects could and could not make shadows. Next, the students were given 10 minutes to do everything they could to not make a shadow with their objects. They were also told to pay attention to what they changed in order to no longer have their objects make shadows.

After the experiment, we held a science talk to discuss which objects made shadows and which did not make shadows. Students were called upon to demonstrate when a discrepancy arose. For example, one group thought that a transparency sheet did not make a shadow, so a representative from another group came to the front of the room to demonstrate how their group created a shadow with the transparency sheet. From the experiment and class discussion, the objective *what you need to make a shadow* (light, object blocking the light, and a surface) evolved, which was then recorded on our KLEW charts along with evidence for their claim. Our student's future wonderings were also recorded. (See Appendix G)

- *Week of February 5th- Color of light and Pre-Test*

This lesson was divided into three stations. At one station, we spun a rainbow colored spinner on an electric drill. When spun very fast, the spinner appeared yellowish-white, which was meant to show the students that light appears yellowish-white because the actual colors of light are moving fast. At another station, students wore refracting glasses, which broke apart the light to allow students to see the rainbow colors that make up light as they looked at four different light sources. At the final station, we gave the students the pre-test. (See Appendix A) The teacher at this station made sure not to give any hints, clues, or suggestions as to the correct answers. Students traveled through the stations with their recording sheets, recording their predictions first, conducting the experiment, and then recording the conclusions at the end of the experiments. (See Appendix B) After students completed all three stations, a science talk was held to discuss what students learned about the color of light, their evidence for what they learned, and any new wonderings. Through the two experiments and class discussion, students were able to conclude that light is made up of the colors of the rainbow, that light moves fast, and that the colors of light can be taken apart and put together. Our students backed up each claim with evidence from the experiments. The claims, evidence, and future wonderings were all recorded on the KLEW chart. (See Appendix G)

- *Week of February 12th – Three Properties of Light*

On day one of this two-day lesson, groups of students were given bins with objects that reflected, absorbed, and allowed light to pass through. Some of these objects included a gold earring, mirror, tissue, transparency sheet, book, and sock. Students were asked to look for similarities amongst the objects and sort them into categories based upon what happened when they shined the flashlight on each object. After students had put their objects into groups and gave titles to their groups, they then had the opportunity to share their categories with the whole class. Finally, we held a discussion about what words scientists would use to name these categories of light.

On the second day, students were asked to find three objects from around the classroom that they hypothesized would reflect, absorb, and allow light to pass through. After their predictions were recorded, they tested them with a flashlight and recorded whether or not their hypotheses were correct. (See Appendix C) During the science talk, students then shared the objects they chose and the reasons for their choices. We also discussed and recorded similarities among objects that reflect absorb and allow light to pass through. This discussion allowed students to pull together and make sense of what they had learned about light over the course of the past two days.

- *Week of February 19th – Scientific Method*

On the first day of this lesson, our classes brainstormed ideas for how to create an experiment that would answer their wondering; "If you change where light comes from will the shadow change?" As a class, they selected one experiment they would carry out the following day to answer the driving question. We also discussed how they would go about recording their hypothesis, steps of the experiment, data and conclusion.

On the second day, the students conducted the experiment they had designed and recorded all of the steps of the scientific method. We then had a science talk and discussed and recorded what they learned from the experiment about how shadows change, their evidence and additional wonderings. From this, students noticed that when the light was moved, the shadow also moved and always appeared behind the object.

- *Week of February 19th- Designing their own Experiments*

This lesson was only completed in Miss Bortner's classroom because her mentor and she felt that it was important to give their students an opportunity to experience the steps of the scientific method first hand. Her mentor and she were also able to include this lesson because the students still had an additional wondering they were eager to find answers to, which had come up in the previous lesson. During this lesson, students worked in groups to design their own experiment in order to answer one of their wonderings, "Which flashlight is the strongest/most intense?" Students then recorded their hypotheses and the steps of their experiment on a scientific method recording sheet. (See Appendix F) On the following day, students carried out their experiment and recorded their data and conclusion. We then discussed whether or not they thought their experiments were fair as well as how scientists measure light by lumens. Students were then given the opportunity to test their two flashlights with light probes, which measured lumens. Much as scientists do, these children were learning that scientists need to support their conclusions with evidence using a variety of methods before others will accept their results as valid.

- *Week of February 26th – Shadow Game*

As our culminating lesson, one student at a time chose an object from around the classroom and placed it on the overhead inside a box so that other students could not see the object. The “chooser” was asked to strategically position the object in a way in which it would be difficult for students to correctly determine what object was on the projection screen. That student then called on other classmates who tried to guess the object. If the object was not correctly guessed within three guesses, that student would then give clues based upon what they had learned about light. Some examples of clues that were given by students included; “My object is shiny.” “My object is reflective.” “My object is opaque.” This game allowed our students to use what they had learned about light and shadows to see that objects do not always look like their shadow, while also reinforcing what is needed in order to make a shadow.

- *Week of February 26th – Post-Test and Survey*

In order to determine what our students had learned during the inquiry science unit, we administered a post- test. (See Appendix D) This post-test was the same as the pre-test given the week of February 5th. We also gave our students a survey to find out what they liked and did not like during the unit in order to analyze the level of student engagement. (See Appendix E)

Data Collection:

We selected a variety of methods for data collection so that we could accurately analyze answers to our wonderings concerning our inquiry-based science unit on light.

1. Student Work

a. Pre-test (Appendix A)

We worked together to create a pre-test based upon the State College Primary Division objectives and Pennsylvania State Standards for third grade for the *Light and Sound Unit,* since we knew these would need to be addressed in our lessons. The students were given 15-20 minutes to complete the seven questions independently and assistance from teachers was not provided. The questions allowed us to see the varying levels of knowledge our students had about light throughout our two classrooms.

b. Post-test (Appendix D)

The same conditions that had been in place for the pre-test applied for this post-test.

c. Color of Light Recording Sheet (Appendix B)

Students brought this worksheet to two stations to help them organize their discoveries about the color of light. This worksheet allowed the students to record the driving question and prediction for each of the two experiments, draw a picture of the actual experiment, and write a sentence about the results.

d. Properties of Light Recording Sheet (Appendix C)

Students brought this worksheet with them around the room as they looked for objects that would reflect, absorb, and allow light to pass through. The students recorded their prediction and reasons for their prediction, and after doing the experiment, recorded the results and reasons for the results.

e. The Scientific Method Recording Sheet (Appendix F)

Our students filled out this recording sheet after they designed their own experiment for their wondering; “If you change where the light comes from, do shadows change?” Candy Stahl provided us with this worksheet that was taken from a graphic organizer booklet (Jacobson & Raymer, 1999). The five steps they recorded were: 1. Ask a question. 2. Come up with a hypothesis. 3. Do an experiment. 4. Record your data. 5. Draw a conclusion.

f. KLEW Chart (Appendix G)

In each of our classrooms we displayed a KLEW chart. On the first day the KLEW chart was used to record what our students thought they knew about light, as well as their wonderings. Throughout the rest of the lessons, this chart was used during science talks to record what our students had learned from the experiments, as well as their evidence and any new wonderings.

2. Student Observations (Appendix H)

During our lessons, we kept a record of key comments made by students before, during, and after the inquiry lessons by writing anecdotal records. These comments were then referred to as we wrote our personal reflections. Students were observed during small group and large group discussions, as well as during one-on-one conversations.

3. Personal, Mentor Teacher, and PDA Observations of Class Discussions (Appendix I)

Both mentor teachers, Candy Stahl and Bonnie Abrams, as well as our Professional Development Assistant, Patricia Begg, observed our lessons and discussed with us what was effective, ineffective and could have been improved upon, as well as additional student observations. Occasionally, these observations were recorded.

4. Personal and Collaborative Reflections (Appendix J)

Both of us recorded written reflections after each lesson of what went well, what could have gone better, and areas that need to be improved, revisited, or elaborated upon. These written reflections were shared with each other, our mentors, and Professional Development Assistant, for suggestions as to what we could have done differently, as well as in which direction our lessons should go next. Also, whoever taught the lesson first would briefly meet with the other to tell them what went well, what didn't go well and give suggestions for their teaching of the lesson later in the week.

Data Analysis

Student Work

"In the context of inquiry, assessments therefore need to gauge the progress of students in achieving the three major learning outcomes of inquiry-based science teaching: conceptual understandings in science, abilities to perform scientific inquiry, and understandings about inquiry" (National Research Council, 2000). It was important that we kept these three learning outcomes in mind while creating assessments for our students and while analyzing student work throughout the implementation of the inquiry-based unit.

The pre-test was administered at the beginning of our project in order to determine what the majority of our students already knew about light and in which direction our lessons needed to go next. At the end of the unit, the pre-test and post-test were compared so that we could analyze the level of effectiveness of our inquiry lessons.

In addition to the pre-test, the predictions recorded on the Color of Light recording sheet were also used to assess the prior knowledge our students possessed about the color of light.

The Three Properties of Light recording sheet was used to assess whether or not the first lesson on the properties of light was effective, which is one example of how we determined the level of conceptual understanding among our students during our inquiry-based light unit. (See Appendix C) This worksheet allowed students to make generalizations as well as use what they had learned about the properties of light to make an educated hypothesis about what types of objects reflect, absorb, and allow light to pass through. Through this, we were able to determine that most of our students had grasped the properties of light objective.

The Scientific Method recording sheet allowed us to see which students were able to use what they had learned about light, as well as the scientific inquiry process, to create a logical hypothesis and experiment to test the driving question, “If you change where the light comes from, do shadows change?” (See Appendix F) We were also able to observe those students who possessed the ability to successfully make a conclusion about their results, explain why they discovered those results, and give their evidence for their claim, which showed an understanding of the scientific inquiry process.

Lastly, the two KLEW charts were used to pre-assess what our student's thought they already knew about light. (See Appendix G) They were also used as a manner in which to motivate our students as they saw how much they still needed to learn about light. These KLEW charts were also used throughout the unit to help us analyze what our students had learned, their evidence for those learnings, and their future wonderings.

Student Observations

- During independent, small group, and large group instruction, we took note of specific comments made by the students and determined which students were: using prior knowledge, using light vocabulary words that had been introduced, using the scientific method to find answers to their wonderings, developing inquiry skills, working as a team, participating, making connections to real-world experiences, engaged, able to focus and remain focused, conveying ideas based on in-depth observations, collecting and sharing data, making generalizations, communicating what they learned, and comparing their predictions to their results. Observing students allowed us to see the success and failure of lessons, whether or not students were engaged, and whether or not they were able to grasp the objective(s) of each lesson. These observations provided us with feedback as to the level of effectiveness of our lessons so that we could determine which areas need to be revisited. All in all, these observations were used to demonstrate the range of understanding within our classrooms concerning the subject matter.

Personal, Mentor, and PDA Observations

- The personal reflections as well as the observations that were made by our mentor and PDA allowed us to see the success or failure of lessons, whether or not students were engaged, and whether or not our students were able to grasp the objective(s) of each lesson. These observations also provided us with feedback as to the level of effectiveness of our lessons so that we could determine which areas need to be revisited or elaborated upon. These observations were used to make necessary changes so that our lessons contained an inquiry focus, and they also allowed us to give each other suggestions for improvement prior to the teaching of a particular lesson. Finally, if a lesson did not run as smoothly as planned, these observations were used to adjust the lesson according to their recommendation.

Personal and Collaborative Reflections

- These written reflections were shared with each other, as well as our mentors and PDA, for suggestions as to what we could have done differently, as well as in what direction our lessons should go next. These reflections helped guide us through the lesson planning process, identify areas of change, and gauge the comprehension level of our students. In addition, we also used these reflections as a method for examining the differences in outcomes and learning styles amongst our classrooms.

Claims

Throughout our investigation of how you take an existing science unit on light and teach it with an inquiry focus, we have learned the following:

Claim A: **In order to teach a unit with an inquiry focus, you need to determine lessons based upon student wonderings, create a student-centered, hands-on environment, and require students to provide evidence for their discoveries.**

Evidence 1A: **The inquiry-based *Light Unit* we developed for science instruction.**

"Guided discovery emphasizes more open inquiry; with 5-E, there are clear objectives and specific concepts and explanations you want children to learn" (Carin, Bass & Contant, 2005). Due to this, we created our lessons based upon the 5-E model of inquiry-based instruction. The 5-E model of instruction was designed by the Biological Sciences Curriculum Study group and includes five phases: *Engagement, Exploration, Explanation, Elaboration and Evaluation* (Carin, Bass & Contant, 2005). Through this model, we presented our students with a driving question, which was derived from their wonderings, in order to get them *engaged* in their learning. We then created an opportunity for students to *explore* concepts about light through hands-on experiments and allowed them to *elaborate* on their understanding by providing them with multiple opportunities to further develop their discoveries. We also allowed them to *evaluate* the concepts learned by having them draw conclusions and *explain* what they learned by providing evidence for their discoveries during science talks. (See Appendix K)

In order to create driving questions, we carefully examined student wonderings recorded on the KLEW chart and compared their wonderings with the necessary Pennsylvania State Standards and objectives. This allowed us to ensure that our students would be engaged during the lessons because the questions came from the students themselves, therefore giving them ownership and motivation to learn something they were interested in. For example, the students in Room 20 wondered when and how shadows moved when the light moved, so we took this exact wondering and developed it into a driving question; “If you change where the light comes from, do shadows change?” (See Appendix K6)

With this inquiry approach, students were given the opportunity to freely explore their wonderings as they learned about light. Many materials were available to them during the experiments, allowing our students to physically manipulate the objects with which they were experimenting. For example, when exploring the three things needed to create a shadow, students were given flashlights and bins of objects ranging from a clear transparency sheet to a book. They were given time to do whatever they could to have the objects make a shadow as well as not make a shadow. Students were not required to follow a specific order or set of instructions while completing this task. During the completion of this experiment, we asked the students questions relating to the driving question to further prompt them in making discoveries about what is needed to make shadows.

In order for the students to deepen their understanding of the three properties of light, two days were spent exploring and utilizing materials around the classroom. Throughout the first day, students grouped different objects into categories according to their similarities and differences based upon what happened when light was shined on the objects. We then discussed what they noticed and students shared their unique category names. On the second day, we reviewed students’ original categories and introduced them to the scientific terms for their categories; reflect, absorb, and pass through. Next, they used what they had learned about the characteristics of these three properties of light to locate an object around the classroom, hypothesize, experiment, and conclude which property that object possessed. This second day allowed students to elaborate upon what they had discovered about the properties of light the previous day. (See Appendices K4 & K5)

After each lesson, students gathered to discuss what they had just discovered about the driving question as well as any new wonderings they possessed. Students were required to back up their claim with evidence from the investigation anytime they shared something they learned that day. This allowed students to begin to understand the importance of giving proof for a scientific statement and helped them see the connection between the experiment and their claim. For example, in both classrooms, during the conclusion of the Color of Light lesson, students expressed that they learned the color of light is rainbow colors. Their evidence to support this claim was that when they looked at different light sources with refracting glasses on, they were able to see rainbow colors because the glasses broke apart the light. (See Appendix K3)

<u>Claim B</u>: Students who struggle with reading and writing excel in scientific inquiry-based lessons.

<u>Evidence 1B</u>: The pre-test administered at the beginning of the unit and that same test given at the end of the unit.

Between both classrooms, those students placed in our lowest level reading groups, as well as those who receive additional support outside the classroom for reading and writing, scored much higher on the post-test than on the pre-test. Since some of the questions allowed for more open-ended responses, we were able to see how these students were able to make connections regarding concepts learned to their own lives and apply new vocabulary and concepts in a variety of situations. For example, on the pre-test one of our student’s responses to the question, “What happens to light when you shine it on an object?” began as “it will macke a shadow” (sic) and on the post-test they wrote, “some Times it go throu or shins on it.” (sic) (See Appendix L1) Another student, in response to the same question, originally wrote, “gos throu, bons [bounce] back,” (sic) but changed his answer to “reflects, stop, or gos through” (sic) when completing the post-test. (See Appendix L2)

For question 3, “How does light move?” one student claimed, “wann [when] the light shut off.” (sic) Her second response was “light goes straight to Tommy*.” (sic) (See Appendix M1) In addition, for the same question, another student originally recorded that, “you move with it.” (sic) During the post-test, he wrote, “the light moves stright [straight].” (sic) (See Appendix M2) All of these responses clearly show how students who struggle with reading and writing excel during inquiry-based instruction.

<u>Evidence 2B</u>: The student work we collected; the Color of Light recording sheet, the Three Properties of Light recording sheet, and the Scientific Method recording sheet.

On the Color of Light recording sheet, all thirteen of our students who struggle in reading recorded the correct answer for the color of light after performing the experiments. Of those thirteen, 8 of those students, 62%, were able to carry that learning to the post-test and correctly answer the question relating to this objective, “What color is light?” (See Appendix N1 & N2)

On the Three Properties of Light recording sheet, these students demonstrated how they were able to connect what they had learned about light the previous day to this day’s lesson. This transfer of knowledge was demonstrated as most of our students who struggle in reading and writing were able to logically predict which objects from around the room would reflect, absorb, and allow light to pass through. These students were also able to thoroughly explain their results using what they knew about the characteristics of objects that hold these properties. For example, one student recorded, “I predict that tinfoil will reflect the light because it’s shiny. My results were the light came back to me because it is so shiny.” (sic) (See Appendix O1) Another student wrote, “I predict the glass door will allow the light to pass through because you can see through it. My results were it allowed the light pass through because it is cler [clear].” (sic) (See Appendix O2)

During the completion of the Scientific Method Recording sheet, a student placed in one of our top level reading groups seemed to be confused throughout the whole process. (See Appendix F) She kept approaching one of us with questions regarding what she should write and how she should perform the experiment. Normally this student is the first one finished with all of her work and is helping other students when they need it. However on this day, she did not know what to write for her concluding sentence for her experiment. When she approached one of us to inquire about the conclusion, the intern was speaking with a student in her lowest level reading group. Before the intern could prompt the student to search for the answer, this student jumped in and proclaimed, “I know! The answer is yes, shadows move when the light moves because the shadow is always behind the object.” The intern was very impressed by this student’s response and she could tell by the smile on his face that he was proud of himself also. This is a perfect example of how a struggling reader excelled in scientific inquiry and was eager and willing to share his acquired knowledge with another, top-level reader and writer, in one of our classrooms.

<u>Evidence 3B</u>: Student observations before, during, and after lessons.

A student receiving Learning Support services in all subject areas came up to one of us one day during recess and was very excited to share an experiment she had conducted at home. She explained to this intern how she had written with marker on a transparency sheet because she was curious about whether or not the writing would make a “shadow” on the wall. She was so excited about her results that during recess she recreated the experiment so that the intern could also see that indeed the marker had made a “shadow”. When the intern asked her what she had learned from this experiment she confidently responded, “I learned that light can go through objects.” The intern then asked her what her evidence was and she replied, “Because light went through the marker and a transparency sheet!” The student then asked if she could share this experiment with the rest of the class, and that is exactly what she did. It was really exciting to see this student, who normally struggles in most areas of school, grasp these concepts about light and excel in an environment where she felt comfortable exploring and making conclusions based on evidence.

We both noticed that the students in our lower reading groups tended to participate more often during these science lessons than other lessons throughout the day, showing us their understanding and confidence in the material. For example, one student demonstrated an understanding of how shadows move by sharing with the class how when the flashlight was placed close to his hand, the shadow was smaller. After moving the light away from his hand, he showed how the shadow grew bigger. Many other students discovered this when experimenting as well.

Another student, during the culminating shadow game, shared that a plastic bag was translucent. When asked what translucent meant, he said, “It is see through.” When asked if translucent objects make shadows, he proclaimed, “Yes!” During this same activity, another student in this struggling reading group, when asked, “Do objects always look like their shadows?” said, “No, not always.” (See Appendix P)

Finally, when a disagreement about whether or not paper could create a shadow arose, one struggling reader made his opinion clear that paper does create a shadow by demonstrating how in front of the class.

Evidence 4B: Mentor and PDA observations of students during the teaching of our lessons.

While recording observations during the culminating activity, one mentor recorded phrases said by students who struggle in reading. (See Appendix Q) This record shows us how these students were able to use what they had learned throughout the unit to strategically select objects to place on the overhead as their classmates tried to guess the object. This mentor carefully took anecdotal records of these clues. For example, she wrote that one of our struggling reading students gave the clue; “It is opaque,” for her object and another student changed the position of his object on the projector to make it easier to guess after his peers struggled at first.

<u>Claim C</u>: Students reach a high level of engagement through scientific inquiry.

<u>Evidence 1C</u>: Student survey distributed at the conclusion of the unit.

Five out of the ten statements that were asked during the culminating student survey were geared towards the emotions of the students in order to assess their level of engagement. For statement 1, "Learning about light was interesting to me.", 62% of our students agreed with this statement by circling a happy face. Statement 3 reads, "I liked making up our own experiment.", and for both of our classrooms, 62% of the students agreed with this statement. The next statement geared towards student attitudes was number 5, "I liked working with others on the experiments." Sixty-four percent of our students agreed that they liked working with others throughout this unit. Finally, for number 8, "I thought finding evidence (proof) for my learnings about light was exciting." 60% agreed with this statement. (See Appendices E, R1 & R2)

<u>Evidence 2C</u>: Student wonderings recorded on the KLEW charts.

During and after experiments, students expressed many further wonderings they had about light as a result of the experiments and our science talks. Many of these wonderings were used as a basis for future lessons. For example, as a result of the first lesson, the Shadow Hunt, students came up with wonderings such as, "How can you make a shadow bigger?" "What makes light reflect?" "If you change where the light comes from, will the shadow change?” “What makes a shadow darker or lighter?” “Can shadows move?” “Do objects always look like their shadow?” “Does an object make two different color shadows?” “Does light bend?” “How does light travel?” and “Do all objects make shadows?” This extensive list of wonderings is proof of how excited and curious our students were about light from the very beginning of the unit. This list only continued to grow after each lesson, as students had more opportunities to develop and grow as amateur scientists. (See Appendix S)

Evidence 3C: Student observations before, during, and after lessons.

Any stranger walking into one of our classrooms during the exploration phase would be able to tell immediately how excited, curious, and intrigued our students were during our inquiry-based light lessons. Hands were constantly raised, eager to share their discoveries and wonderings with us as well as their peers. The busy bustle of students hard at work may have appeared to outsiders as chaotic; however, this was simply the students’ ways of expressing their excitement and newfound understandings about light. During science talks after the completion of the experiments, students were very anxious to participate and share their new learnings as well as their evidence for those learnings with the class. Many hands were raised and the percentage of students off task was unusually low. For example, several students between our two classrooms who are usually very fidgety were more calm and involved during the science talks. Also, we noticed that students who are usually timid about raising their hand and sharing their ideas, were much more confident and willing to raise their hand to participate in the discussions.

<u>Claim D</u>: It is possible to meet all objectives and state standards while teaching science through inquiry; however, due to time constraints, it is difficult to touch upon all student wonderings.

<u>Evidence 1D</u>: A specific question on the post-test relating to how light travels.

On the post-test, 84% of our students incorrectly answered the question, "How does light travel?" This light concept was taught briefly, in combination with another lesson that focused more on the Pennsylvania State Standards and objectives than on student wonderings. Although this was a wondering expressed by the students, time did not allow for a lesson catered towards this wondering, which is why we believe 84 % of our students did not develop a conceptual understanding of how light travels.

In order to assure that we met all standards and objectives, we had to lessen the emphasis placed upon some wonderings and increase the emphasis placed upon others. Keeping this in mind, we were not able to touch upon some student wonderings. However, this inquiry approach allowed our students to deepen and expand their knowledge about a few light concepts. For example, our students not only learned the objectives: what three things are needed to make a shadow, all objects make shadows, the color of light, light travels in a straight line and the three properties of light, but they also learned when and how shadows change, the color of shadows, the fact that objects don't always look exactly like their shadows, and that all objects make shadows. They also learned the steps of the scientific method, such as how to create a hypothesis, experiment, and draw conclusions that were consistent with the data collected. They gained knowledge about how to create a fair experiment, give proof for scientific claims, and discovered that when light is close to an object the shadow is smaller, but when it is further away, the shadow gets bigger. It is truly remarkable how teaching light using an inquiry approach allowed our students to learn all of these scientific concepts and processes in addition to the objectives.

Evidence 2D: Student wonderings on the KLEW charts.

Most of the wonderings that our students came up with were objectives that we needed to touch upon in our classrooms; however, this did take a bit of creativity because we had to develop focus questions that would specifically target the objectives, while still meeting the wonderings of our students. For example, many of our students wondered if shadows came in different colors so we incorporated this wondering into the larger objective, “What do you need to make a shadow?” We did this by selecting objects for students to test that would create “colored shadows” and as the students tested these objects, we asked them if they thought the object was making a shadow or not and why. Students were expected to give answers about colored shadows based upon what they had discovered was needed to make a shadow.

At one point, due to the time constraints and the need to teach all of the objectives, we had to teach the color of light lesson by providing our students with the driving question, “What is the color of light?” However, this was the only lesson in which we created the driving question, rather than having our students create it.

In both of our classrooms, students expressed many wonderings about the sun, how flashlights work, and how lights work in general. Unfortunately, due to time constraints and the fact that these were not objectives for second graders, we were unable to touch upon these wonderings.

Claim E: During team teaching and collaboration, the pros outweigh the cons.

Evidence 1E: Discussions with mentors, PDA, and each other before, during, and after each lesson.

With our mentors, we would receive feedback after teaching our lessons on what we should add or do differently to our lessons to make them more inquiry-based. For example, one of our mentors commented on a way for us to extend our lesson and assess student understanding by requiring them to apply their knowledge learned about how shadows change, therefore increasing the level of inquiry. She stated, “Have them test a new object and predict what the shadow will look like when they shine the light at various objects. Outline what will happen and then shine the flashlight to see if they are correct. Or have them play a Shadow game—select an object and turn it different ways to see how the shadow looks. Predict first and then test” (Stahl, personal communication, February 15, 2007). We took her comments, incorporated them into a lesson, and had our students create their own experiment to find an answer to their wondering, “Do shadows always look like the object?” We also took her advice and created our culminating lesson, another assessment tool, in which students used their knowledge about light and how shadows are made to stump the class as they placed objects on the overhead projector.

All of our mentors’ suggestions were taken into consideration when planning for the next lessons, as we began to develop and become more confident with our ability to teach inquiry. Throughout the lessons, our mentors would also assist during the science talks to further students’ understandings and wonderings. For example, during the Properties of Light lesson, one mentor extended the students’ thinking by holding up a few transparency sheets which students knew allowed light to shine through. Then she continued to add more and more until the students could hardly see through them anymore. She then asked the students if they thought the light would go through now. This deepened students’ understanding that thicker or opaque objects block light and that light goes through some objects more easily than others. Also during this lesson, my mentor, who had been working with two students testing the strength of their flashlights, commented on how one of the students found that the paper absorbed the light and the other student found that the light passed through the paper. By broaching this subject to the class, my mentor was able to lead the students to a new wondering of whether or not some lights are more intense than others and how the whole class could test the intensity of a light. Our mentor’s experience with teaching inquiry was very helpful in providing us with insights into how to best develop lessons based upon student wonderings. Their expertise also helped us see the importance of listening to our students during investigations so that we could then bring their questions and discoveries to the class for discussion.

Collaborating with our PDA was also beneficial in many ways. She was able to provide us with additional feedback on our lessons before, during, and after the implementation of them. Much like our mentors, she was able to give us feedback about how we could improve our lessons to make them more inquiry-based. For example, when one of us first taught the Three Properties of Light lesson, our PDA observed us and noticed that we were doing too much prompting and were therefore not teaching true inquiry. Through her suggestions, we were able to improve this lesson for when the other person taught it in their classroom a few days later. We discussed how to transform the lesson into a necessary two-day approach and she told us to ask more open-ended questions so as not to limit students' ability to freely explore. After this discussion we took her suggestions and began asking more questions such as, "Why?" "How?" and "What do you think?"

We also changed the Three Properties of Light lesson because instead of having students divide the objects into *three* categories, we told them to sort them into as many categories as they felt necessary. Some students grouped their objects into categories that were not based upon the actual three properties of light; however, we did not tell them their categories were incorrect. Our PDA also provided us with examples of other objects that would allow our students to understand the properties of light more clearly. For example, we originally had the students shining a flashlight at a paper clip to see that it was reflective; however, this object created confusion because the light passed through the holes of the paperclip. Therefore, the second time this lesson was taught, aluminum foil was used instead of the paper clips to demonstrate light's reflective property. Many of our lessons were improved due to her assistance.

Although we planned together, our lessons were never taught collaboratively. All of our lessons were written together so that we could feed off each other's ideas for how to best meet the objectives, standards and student wonderings. All of our lessons were taught on separate days so that when one of us would teach first, we would meet with each other to discuss what went well and what we would change to make the lesson more inquiry-based. For example, after the first lesson, one of us noticed that the students were stuck on the idea that shadows can be different colors. The intern who taught the lesson was not sure how to best help her students understand that all shadows are black; therefore, she missed a teachable moment and the misunderstanding was not cleared up. This intern shared this experience with the other intern who was going to teach the same lesson the following day. This communication helped the other intern teach this lesson because since her students also shared their beliefs that a shadow could be different colors, that intern was prepared to discuss and expand on students' curiosity. Teaching collaboratively also helped us differentiate science instruction in our classrooms. For example, if in one of our classrooms we noticed that our students who struggle in reading and writing were struggling during our light lessons, we would talk to the other and give them ideas for how to better differentiate instruction for that group of students.

Evidence 2E: Sharing of resources and materials.

Teaching these lessons would not have been possible without each other. From writing lesson plans to gathering materials for a lesson that afternoon, we helped each other in any way possible. Much like the novice inquiry teachers in *Inquiry and the National Science Education Standards*, " [We] learned how to learn with and from others pursuing similar scientific questions, the importance of models and materials, and how to communicate [our] findings to others" (National Research Council, 2000). Not only did we help each other, but we also had support from our mentors and the other primary teachers. One of us taught lessons in a first grade and second grade classroom. Also, when we were not available to do the teaching in another classroom, we shared our lesson plans and any materials needed with the other primary teachers. At the beginning of the unit, a letter was sent home to parents requesting their child bring in a flashlight for the unit; however, not all students were able to contribute a flashlight. In order to ameliorate this problem, we shared flashlights between our classrooms. Due to all of these reasons, collaboration served as a pro during the planning, preparation, and teaching of our inquiry lessons.

<u>Evidence 3E</u>: Differences in student prior knowledge, understandings, and abilities amongst our classrooms.

Despite the many differences in student prior knowledge, understanding, and ability between our two classrooms, a final benefit we discovered about collaboration was that we were able to use these differences to our advantage. For example, one of our classes came up with the wondering, "If you change where the light comes from, do shadows change?" The other classroom did not come up with this wondering; however, we believed that this would help both classrooms better understand light concepts, so we created a lesson based upon this wondering for both classrooms. This wondering was brought up to the students in the other classroom and even though they had not created this wondering on their own, they knew that other second graders down the hall did. After hearing that, it was obvious through comments and facial expressions that they became interested in the wondering as well.

Another way in which we used the different abilities among our classrooms to our advantage is best described in an example. In one of our classrooms, a student came up with a simple way to remember the scientific terms for the three properties of light. This was shared with the other classroom in order to simplify their learnings. If we would not have collaborated throughout our inquiry lessons, the students in one of our classrooms would never have learned the unique way of remembering the scientific terms for the properties of light.

Conclusions

As a result of this collaborative inquiry project, the learnings we will bring with us on our journey throughout our careers in education are immeasurable. In our future teaching, based upon what we have learned from this experience, we will prepare to be unprepared, be flexible with the time allotted for teaching inquiry lessons, not be afraid to take teachable moments and run with them, ask "Why" without hinting towards the answer, extend student thinking, engage our students, improve science talks, and incorporate more student wonderings into our lessons.

First, we have learned that while teaching inquiry, you must be prepared to be unprepared. It is impossible to know the direction your lessons will take because it is up to the students' wonderings and discoveries to determine the route for each lesson. During a lesson, one of us felt unprepared when the students began discovering that the light passed through the hole in the paper clip, not that the paper clip reflected the light because it was shiny. This was due to the fact that we hastily compiled the bins of objects for students to test. We did not test the objects prior to the lesson due to time constraints and therefore, these items were not the best choices to demonstrate the properties of light.

Also, during a science talk after the Colors of Light experiment, a student brought up rainbows and wondered how they appear. The intern was taken back by this comment because she had never thought about it and felt unprepared. However, she put the question back at the students and one student knew the answer. Students often came up with responses that we had not planned for, but when we listened to their explanations they usually were logical and could be backed up with evidence. Although we were not able to anticipate everything, it was what we were able to do in response that mattered!

We also learned about the importance of time when teaching inquiry. Our lessons required extensive amounts of time so that students could experiment and reach conclusions on their own. One of the most critical components of each lesson were the science talks, which also required a lot of time as students shared their ideas, fed off of their peers' ideas, and posed future wonderings. If twenty minutes was planned for a science talk, but an exceptional question or comment was raised, it was important for us to not be afraid to take those teachable moments and run with them. In order to do this, time was of the essence. As our PDA put it best, "Inquiry doesn't necessarily allow for fast. You have to be able to give students the time they need to develop deep understanding" (Begg, personal communication, March 2007). This quote perfectly sums up the importance of taking the time to teach valuable inquiry lessons.

Little did we know that throughout our first few lessons, we were not teaching inquiry at the level we had hoped. With assistance from our PDA, it was brought to our attention that we were prompting our students too much and not allowing them to explore enough on their own. "Inquiry based approaches require that students engage in several activities such as brainstorming, generating questions, finding and applying information, and justifying data and results. Teachers in this environment are simultaneously managing content and process that requires them to be masters of both” (Goldstein, Puntambekar & Stylianou, 2007). As we began to gain more understanding of the light content and inquiry process, we learned the importance of asking “Why?” and not giving too much away. Through this, we learned that inquiry is about the teacher acting as a guide as they lead their students in the direction of where they can find the answer on their own.

Due to the fact that our lessons came from student wonderings, we found our students engaged and motivated to learn about light. Motivation is one of the key factors for creating a classroom environment that allows for free exploration and learning. Through this motivation, we were also able to see our students develop a deep and broad understanding of light concepts through the inquiry approach as we extended students’ thinking and encouraged them to explore outside the box.

Although the students were engaged during the experiments, sometimes the science talks lacked participation from all students. This left us questioning whether we had been able to meet all of our students’ needs. Learning how to improve our science talks so that all students participate is a goal for the both of us for our future teaching. We feel that after gaining confidence in teaching inquiry, we will be able to focus more of our energy on ensuring participation from all students.

Unfortunately, we were not able to address as many of the students’ wonderings as we would have liked. Due to time constraints and the data needed in a timely manner for this project, we had to pick and choose which wonderings best fit with the objectives and standards set by the state. In the future, we both plan to experiment with ways in which we could incorporate more student wonderings at one time.

In the years to come we will take what we have learned and continue to grow as teachers of inquiry so that we can provide all of our students with an environment in which they are encouraged to learn, share, and ask questions.

Future Wonderings

As we began to reflect upon our inquiry project, we realized that there was a lot we learned through this process; however, there are still unanswered questions in our minds that we would like to learn more about. The following is a list of questions that we would like to find answers to later on in our careers:

- In an inquiry-based science unit, will students generate connections to content more easily than in a teacher-directed science unit?
- Are inquiry-based lessons on light as effective in a first grade classroom as they are in a second grade classroom?
- How can we allow students to explore those wonderings that do not fit objectives?
- How can we encourage participation by all students during science talks so that we can best assess student learning?
- How do students who excel in reading and writing perform during scientific inquiry? How do the understandings of these students compare to the understandings of students who struggle with reading and writing?
- What are the similarities and differences between how first and second grade students understand the concepts of light using an inquiry approach?
- What is the level of effectiveness of inquiry-based science from a kindergarten classroom through a fifth grade classroom?
- Can inquiry be applied to any elementary subject matter?