2018

The Impact Of Problem-Based Learning In An Eighth-Grade Earth Science Classroom: An Action Research Study

Caroline Lucinda Moon
University of South Carolina

THE IMPACT OF PROBLEM-BASED LEARNING IN AN EIGHTH-GRADE EARTH SCIENCE CLASSROOM: AN ACTION RESEARCH STUDY

by

Caroline Lucinda Moon

Bachelor of Science
University of Georgia, 2010

Master of Arts in Teaching
University of Georgia, 2011

Submitted in Partial Fulfillment of the Requirements

For the Degree of Doctor of Education in

Curriculum and Instruction

College of Education

University of South Carolina

2018

Accepted by:

Christopher Bogiages, Major Professor

Rhonda Jeffries, Committee Member

Christine Lotter, Committee Member

Stephen Thompson, Committee Member

Cheryl L. Addy, Vice Provost and Dean of the Graduate School

Dedication

I dedicate this dissertation to my loving parents,

Cindy and Rick.

Thank you for always being there for me,

And encouraging me to pursue my dreams.

Acknowledgements

I would like to express gratitude to so many people who were an integral part of the creation of this dissertation. I would like to offer thanks and appreciation to my advisor, Dr. Christopher Bogiages. Your advice, feedback, and guidance have led to tremendous growth in my teaching practice and helped me create an impactful and meaningful action research study. To everyone involved in this study, especially my eighth-grade students, thank you for your participation as your efforts and honesty made this endeavor possible. To my team members with whom I work every day, thank you for your constant support and kind words that you have given me throughout the past three years. To my parents, Rick and Cindy, thank you for always encouraging me to pursue my dreams and value the importance of education. You have offered a support system that holds me up and never lets me fall too far.

Abstract

The present dissertation in practice (DiP) proposal delineates an action research study designed to evaluate the use of problem-based learning (PBL) in an eighth-grade earth science class to assess the impact of PBL on student achievement. I have observed that students often struggle with developing an understanding of how the motions of the sun, earth, and moon (SEM) cause observed phenomenon on the earth. In addition, I have observed the unintentional marginalization of cisgender female students within the science classroom. The identification of the problem of practice (PoP) led to the development of the following two research questions: *How does PBL impact the conceptual understanding of students in an earth science class? What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom?* The study used an action-research methodology and followed the four-step cycle of *planning, acting, developing,* and *reflecting*. During the planning phase, I developed a problem of practice, conducted a literature review, and developed a research plan. The acting phase involved the collection and analysis of data. The developing phase involved the implementation of an action plan using the collected data. The reflecting phase involved a systematic reflection of the study and the communication of results. The findings of the study show that PBL was somewhat effective in bringing conceptual change in this study. In addition, the actions of the PBL tutor can create a more equitable science classroom, PBL may reduce confusion in science class, and risk-taking is an important aspect of the PBL process.

Keywords: action research, problem-based learning, student achievement, science education, gender equity

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List of Abbreviations

CI .... Complex Instruction

DiP .... Dissertation in Practice

K–12 .... Kindergarten–12th grade

PBL .... Problem-Based Learning

PoP .... Problem of Practice

STEM .... Science Technology Engineering and Math

Chapter 1:

Introduction

As an eighth-grade earth and space science teacher, I have experienced the difficulty of addressing the misconceptions that impact student learning. The use of lecture-based instruction in my classroom has shown to be ineffective in guiding learners to an understanding of complex and abstract scientific phenomena grounded in evidence. Students experience difficulty when attempting to integrate abstract concepts taught in class into their mental schema. Even after science instruction has taken place, students may have lingering misconceptions regarding the concepts learned in class. For example, when teaching space science, many students have wild ideas about how the moon, earth, and sun move in space, or they may contain incorrect notions of why the earth experiences seasonal change. Ideas and understandings such as these often deviate significantly from an evidence-based scientific understanding; the preconceptions and alternative conceptions often remain even after science instruction has taken place in my classroom. Students may leave eighth grade with without fully reshaping their conceptual understanding of these everyday phenomenon. In addition to the issues of learning associated with attempting to grasp complex or abstract science concepts, social factors influence the learning environment. In my own classroom, I may be unknowingly contributing to the reinforcement of gender stereotypes, leaving female students underserved within the science classroom, thus propagating the marginalization of women in science. In my classroom, the cisgender male students tend to dominate class discussion. For example, when I ask a question to the entire class, very rarely do the cisgender female students volunteer to answer, whereas many of their cisgender male peers readily raise their hand to answer.

These problems are not just my own. Goals of science education are often left unmet when the science curriculum focuses on the memorization of facts, covers concepts in breadth over depth, and lacks engaging opportunities to understand how scientists actually do their work (Chiappetta & Koballa, 2010). Students enter the learning environment shaped by their everyday experiences. These experiences often reinforce ideas scientific evidence has shown to be false. Learning is traditionally viewed as the adding of new skills and facts on top of what is already known by the learner; however, understanding scientific knowledge often requires a change in what people comprehend and notice about everyday phenomenon (Donovan & Bransford, 2005). Conceptual change can be encouraged through engaging students in active investigation and inquiry into the concept being studied (Chiappetta & Koballa, 2010). In addition, science is traditionally viewed as a male-dominated endeavor, and participation by women in science may be negatively impacted by gender stereotypes. While there has been an increase in women in science, technology, engineering, and mathematics (STEM) careers over the past 40 years, men still outnumber women in these fields (Miller, Eagly & Linn, 2014; Perry, Link, Boelter, & Leukefeld, 2012).

The current action research study investigated my perceptions as the teacher-researcher while I conducted a series of PBL scenarios in an eighth-grade earth science classroom. The PBL scenarios served as a vehicle to deliver conceptual change to the student-participants, while I also attempted to disrupt the stereotypical gender norms that may marginalize female students in the science classroom. Chapter 1: Introduction provides a summary of the entire action research project. Chapter 2: Literature Review is an overview of the relevant literature in PBL, modeling, gender bias in science education, and conceptual change. Chapter 3: Methodology describes the methods used for data collection in the action research study. Chapter 4: Findings and Implications provides an evaluation of the collected data and an analysis for possible trends. Chapter 5: Summary and Conclusions includes a discussion of the meaning of the findings and a detailed action research plan.

Problem of Practice

The identified problem of practice (PoP) for the present action research involved my current teaching practice in an eighth-grade science classroom. As a teacher, I have experienced great difficulty attempting to bring eighth-grade students to an evidence-based conceptual understanding of abstract science concepts. When I use lecture-based instruction, students sometimes struggle to connect the content to their personal experiences outside of the classroom. In addition, I have observed the unintentional marginalization of female students in the science classroom, as this environment has traditionally favored male students. Students often leave the classroom with lingering misconceptions or lack of conceptions about abstract scientific phenomena. Traditional lecture-based instruction is thought to be ineffective in activating long-term memory of content and in motivating student students to learn (Norman & Schmidt, 2000). Lecture-based instruction has proven unsuccessful in increasing student improvement in critical thinking and developing problem-solving skills (Han, Capraro, & Capraro, 2015). The goal of the action research study is an attempt to find an instructional methodology to foster conceptual change with a class of eighth-grade earth science students at a rural middle school in the southeastern United States while creating a more equitable classroom for all students.

In addition, the underlying issues of gender, race, and class impact the classroom environment. Gender often appears as a binary represented through traditional stereotypes assigned to the behavior of girls and boys. These stereotypes are prevalent throughout society and socially reiterated from birth. Hackman (2013) argued:

> gender roles are rigid categories (and there are only two) that characterize what it means to be "feminine" and "masculine" in this society … our families tell us how to behave, our schools tell us what we can achieve, and our media tells us what we need to look like. (p. 318)

Bazzul and Sykes (2011) charged that schools continue to marginalize students, as they may propagate oppressions related to gender. For example, Tidermann (2002, as cited in Carl, 2012) observed that the gender biases of teachers may support that girls do not do as well in math as boys; this view may impact their behavior towards girls and boys in the classroom. Gender stereotypes are often created as a binary and are silently enforced through the behavior and actions of people (Hackman, 2013). As an educator, it is important to create an inclusive classroom for all students, regardless of sex and gender identities.

The middle school is referred to by the pseudonym "Shannon Middle School" (SMS). As the teacher-researcher, I have described my perceptions while implementing a series of PBL scenarios in an eighth-grade earth science classroom. I have also included a description of the impact of the PBL framework (McConnell, Parker, & Eberhardt, 2017) on the conceptual understanding of the student-participants (see Appendix A). The PBL learning model used in this action research study has not been used at SMS in the past. Instructional strategies focused on the disruption of stereotypical gender norms that may otherwise be reinforced in the classroom setting in an effort to create a learning environment supportive of all students. The PBL curriculum served as a mechanism to deliver an evidence-based understanding of science concepts to all students while disrupting stereotypical gender norms present in an eighth-grade science classroom.

Theoretical Framework

The theoretical framework for this action research study is grounded in conceptual change theory, cognitive constructivism, problem-based learning, developing and using scientific models, and gender bias in science education. Through the use of PBL within an eighth-grade science classroom, I have attempted to guide my students to a conceptual understanding of scientific concepts while disrupting gender norms. Science teachers are often met with the difficult task of bringing all students to an evidence-based understanding of a scientific concept within a complex and dynamic science classroom.

Conceptual change theory recognizes how students enter the classroom with their own ideas and conceptions about scientific phenomenon. Often, what students believe to be true does not align with an understanding grounded in scientific evidence (Chiappetta & Koballa, 2010). Posner, Strike, Hewson, and Gertzog (1982) argued that to bring conceptual change to a learner, several conditions are essential:

1. The students must be dissatisfied with their existing views
2. The new conception must appear somewhat plausible

3. The new conception must be more attractive than the previous conception
4. The new conception must have explanatory and predictive power (as cited in Stepans, 2006).

Driver (1988, as cited in Chiappetta & Koballa, 2010) recommended an instructional sequence to conceptual change based on conceptual change theory where the teacher first *orients* the students to what is to be learned. The teacher *elicits* the students to explain their ideas about the topic under study. Following elicitation, the teacher calls for the students to *clarify* their understanding. The teacher then creates a *conflict* scenario and provides the students with a discrepant event that causes the student to begin to understand that their initials thoughts may be incorrect. In this study, the conflict scenario was in the form of a *transfer task* question where students had to apply what was learned from the PBL to a new and slightly different scenario (McConnell et al., 2017). Driver (1988, as cited in Chiappetta & Koballa, 2010) continues as students then engage in *construction* as the teacher helps guide the students to view their ideas differently and to provide evidence-based explanations. An opportunity for *application* is necessary where the teacher offers instances where the student can apply what he has learned. The teacher should give the student an opportunity to *review* how her conceptions may have changed from the beginning of the instructional unit to the present.

The PBL pedagogical aligns with cognitive constructivist educational theory (Savery & Duffy, 2001; Savin-Baden & Major, 2004). Constructivism holds that the learner constructs knowledge based on their previous understanding and their views of the world (Savin-Baden & Major, 2004). Students using PBL have the opportunity to build knowledge for themselves. During PBL, students are expected to think critically and to monitor their understanding of the topic under study (Savery & Duffy, 2001). Solving problems can be a foundation of developing cognitive structures. Bruner (1997) argued that the more a teacher approaches the learning process by discovering "rather than 'learning about' it, to that degree there will be a tendency for the child to work with the autonomy of self-reward or, more properly, be rewarded by the discovery itself" (p. 88). Bruner advocated that the practice of discovery and solving problems lead to the ability of a learner to create solutions for problems encountered in the future. PBL shifts students away from teacher delivered lectures; instead, students learn by engaging in the learning process while creating solutions to a problem scenario (Savin-Baden & Major, 2004).

PBL originated as a strategy in medical schools in the late 1960s and has expanded into other disciplines including kindergarten–12th grade (K–12) education (Savery, 2006; Savin-Baden & Major, 2004). During PBL, students are engaged in the learning process through their immersion in a problem scenario as the teacher or PBL tutor presents a real-world problem with no definitive answer. Students work in teams to isolate the information needed to create a potential solution to the problem. The teacher acts as a guide, tutor, or coach to facilitate the learning process. Proponents of PBL argue that the strategy leads to the development of problem-solving abilities (Savin-Baden & Major, 2004). Students work collaboratively while solving a complex problem to build knowledge and the learning process is considered student-centered (Barrows, 1986, 1996). Hmelo-Silver and Barrows (2008) argued that there are several factors critical to building knowledge during a successful PBL learning experience:

1. Students must be engaged in a problem that helps them better understand the world.
2. Students must actively work to improve their understanding of a concept.
3. Students also must understand how their understanding fits with the understanding of others to then work together to develop a solution.
4. There must be a collective responsibility to advance the understanding of the group. Participants must use a variety of sources to validate their stance.
5. Finally, a discourse must occur where students construct and refine knowledge while discussing their findings with others

PBL is grounded in the philosophy of John Dewey, who believed that “education begins with the curiosity of the learner” (Savery, 2006, p. 16). PBL provides an environment for students to cultivate self-directed learning skills, develop skills for the workforce, and try out new ideas in a safe environment. PBL gives students the opportunity to conduct research and apply their knowledge to develop a solution to a problem (Savery, 2006). During PBL, students engage in a problem without much prior knowledge and the teacher does not give the students enough information to solve the problem; therefore, the learners must extend their knowledge through research or other instructional opportunities. Then, they must apply this information to generate a possible solution to the problem (Wirkala & Kuhn, 2011). PBL uses these ill-structured problems as a context for students to acquire problem-solving skills and learn specific content (Albanese & Mitchell, 1993). An ill-structured problem is one without a single definitive solution and is designed to motivate students to ask questions and seek information;

students will construct knowledge while working to develop a solution to an ill-structured problem (Wirkala & Kuhn, 2011).

Within PBL, model creation can be an essential aspect of developing cognition (McConnell et al., 2017). Models can be physical, mathematical and conceptual—these models can serve as tools for learning the things that they resemble (AAAS, 1990). Bruner (1997) notes "a small but crucial part of discovery of the highest order is to invent and develop effective models" (p. 94). Schwarz and White (2005) argue how students may benefit from using, revising, and creating scientific models that represent their own mental understandings of phenomena. Science education attempts to take students' conceptual models and manipulate them to include more advanced scientific knowledge. This process requires a carefully crafted instructional sequence. It is the role of the science teacher to help students acquire scientific conceptions and introduce students to the culture of the scientific community (Chiappetta & Koballa, 2010).

Throughout the action research study, I have attempted to disrupt stereotypical gender norms present in an eighth-grade earth science classroom. Therefore, throughout the study, I have viewed the learning environment through a lens of intersectionality. Intersectionality is the exploration of the interrelationship of gender, race, and class (hooks, 2013). Science education in the United States is Western in nature and historically patriarchal; to assist students in crossing these borders, I believe in playing an active role in breaking down stereotypical gender roles. Gender is a diversity issue critical to the theoretical framework of this action research study, as I have attempted to create a science classroom that empowers all students. Through this action research study, I have tried to disrupt the societal pressures the students in my classroom face through the creation of a learning environment supportive to students of all genders. Gender stereotypes and other biases may appear in the classroom as everyone, both teachers and students, carry their own biases (Paterson, 2017). Their everyday experiences shape students, and the school environment plays a significant role in contributing to student understanding of the world. Learners may hold a stereotypical view of what it may mean to be a scientist or engineer, and it is the role of the educator to bring the student to a more appropriate and richer understanding of science and engineering (Farland-Smith & Tiarani, 2016). An in-depth discussion of the theoretical framework is included in Chapter 2: Literature Review.

Research Questions

To examine the effects of PBL and the experiences of the teacher-researcher implementing the PBL, I asked the following research questions:

1. How does PBL impact the conceptual understanding of students in an earth science class?
2. What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom?

These questions served as the framework used to gain insight into my experiences as the teacher-researcher implementing the PBL and to describe student conceptual change throughout the action research study while disrupting stereotypical gender norms.

Research Design

As the teacher-researcher, I have observed the difficulty students experience when developing evidence-based mental models of the SEM system. Through action research, I have described my perceptions implementing a series of PBL scenarios in my own classroom. Action research is a powerful tool that can be used by educators to address problems unique to their classroom with the possibility of finding immediate solutions (Mertler, 2014). Action research addresses an individual problem within the classroom and focuses the inquiry of the teachers for the further development of curriculum. The process of action research serves as an inquiry into my own practice as a science teacher (Dana & Yendol-Hoppey, 2014; Mertler, 2014). I have evaluated the impact of PBL pedagogy in my own classroom through Mertler's four-step action research cycle (see Appendix B) in an attempt to bring conceptual change to students and disrupting stereotypical gender norms that may marginalize female students. The research methods are based on the four stages of action research: planning stage, acting stage, developing stage, and reflecting stage.

I used a qualitative design procedure in the form of an intrinsic case study within the action research design process. Qualitative research can provide a more holistic picture of what goes on in a particular classroom or school and can be used to focus on the experiences of the participants involved in the study (Creswell, 2014; Fraenkel, Wallen, & Hyun, 2015). In an intrinsic case study, the researcher is interested in understanding as much as possible about a specific situation. As I am describing my experiences as a new PBL tutor, I am the focus of this intrinsic case study (Fraenkel et al., 2015). A qualitative design methodology was appropriate as the goal of the action research study was to capture a reflection of my experiences as the teacher-researcher new to PBL.

Driver's (1988, as cited in Chiappetta & Koballa, 2010) conceptual change instructional sequence was employed in the action research study, as students created drawings and explanations of their own understanding of a science concept prior to instruction and engaged in a conceptual change instructional sequence integrated with PBL. Students participated in a series of PBL scenarios designed to create conflict within the initial mental models of the student; through the PBL experience, learning opportunities were provided to help students view their ideas differently and to promote scientific discourse about complex phenomena. Following construction and evaluation, the students were given a new and slightly different instance to apply what has been learned in a *transfer task question* (McConnell et al., 2017). The students were also asked to describe how their initial understanding has changed after the PBL experience by evaluating their first representation.

I collected data throughout this process in the following forms: Pre- and post student-created representations evaluated by a teacher-created rubric, video blogs created by the students at the beginning and end of the instructional sequence, a reflective journal maintained by the teacher-researcher throughout the entire study, observations of the PBL implementation by two colleagues of the teacher-researcher, an analysis of student artifacts of learning, and two focus group interviews conducted with six female students before and after the PBL learning cycle. I collected data in an attempt to gain insight into my perceptions as I attempted to bring conceptual change to my students and create a more inclusive classroom for all students. Each form of data collection is discussed in greater detail in Chapter 3: Methodology.

Purposive sampling was used to determine the student-participants of this study. Purposive sampling is used to select a sample that will provide the best understanding of the research questions (Fraenkel et al., 2015). Data collection occurred throughout the eight-week action research study. As the teacher-researcher, I continuously observed the student-participants, and I have supplemented my observations with interviews of selected participants. I collected qualitative data about my experiences as the PBL tutor in the form of daily reflections maintained in a journal (Creswell, 2014). Data for the study were coded for meaning as themes emerged; I used selective coding where tags or labels were generated to give sense to chunks of data (Fraenkel et al., 2015).

Because this is a small study in a classroom outside of a typical controlled research environment, the results are not generalizable to a larger population (Mertler, 2014). The ideas from the qualitative data acquired from this action research study can be shared and used for future investigations. Those interested in using PBL in the classroom could potentially use the inferences made in this action research study. Teachers may benefit from this action research study if they are interested in integrating PBL into their teaching practice. Researchers may use this action research study to identify areas of future research regarding PBL in K–12 education. I have described the action research study including myself as the teacher-researcher, the research context, the student-participants, and the researcher-participant relationship so that the reader of the study can decide how the finding may transfer to a different environment (Fraenkel et al., 2015). The design of the action research study is discussed in further detail in Chapter 3: Methodology.

Positionality

Through this action research study, my interest was in the use of PBL as a method to foster conceptual change within my students. PBL was also used as a vehicle to eliminate stereotypical gender norms that may marginalize female students. Through the action-research process, I have attempted to gain insight into my role as a teacher within the PBL scenarios through the collection and analysis of a variety of qualitative data. I have described inferences into the understanding of the student-participants by interpreting artifacts representing their understanding of the SEM system and evaluating their representations in comparison to evidence-based scientific models of the SEM system. Because I was directly involved in the research process as the teacher-research, there was a high risk of collector bias in the study (Fraenkel et al., 2015). Therefore, data are reported with as little bias as possible to reduce potential collector bias, taking care not to overlook any applicable student data. I had only used PBL as a strategy one time before this action research study; my lack of experiences as a PBL tutor may have impacted the effectiveness of the use of the PBL pedagogy within my classroom.

Participants

The student-participants in the current action research study are from a class of 27 students in an eighth-grade earth science classroom in a rural school in the southeastern United States. The purpose of the study was not to generalize the results to the broader population; therefore, purposive convenience sampling was appropriate for this action research study (Fraenkel et al., 2015). As I am an eighth-grade earth science teacher, the sample for the action research study included students in one of eight of the classes I taught during the action research study. The majority of students at SMS are White. In general, students who attend SMS are motivated to do well academically.

The class of student-participants includes 27 students between the ages of 13 and 14. Twelve of the students are female; fifteen of the students are male. Eighteen percent of the student-participants receive free or reduced lunch, which is lower than average school population where 25 percent of the students are eligible for free and reduced lunch. One student has a 504 instructional plan. All of the students are fluent English speakers. All of the students in the study are in either honors English or honors algebra, which are high-school-level courses.

Ethical considerations are paramount to any research endeavor. Any individual who handles data maintains ethical responsibilities of the collected information. All data collected represents an attribute from the person it was collected and are pieces of an individual history (National Forum on Education Statistics, 2010). Ethics were at the forefront of every decision in the research process as I maintained a code of honesty, caring, and fairness toward each participant (Mertler, 2014). My ultimate goal was to do no harm to any of the participants during the action research process (Dana & Yendol-Hoppey, 2014).

Privacy protection of each student is critical. I used pseudonyms when discussing individuals in the action research study, and I coded data in a way that protects anonymity. Students and parents were made aware of the details of the study and were informed that opting out of the research process is possible at any point (Dana & Yendol-Hoppey, 2014; Mertler, 2014). Because the action research study was for the completion of a culminating project for a dissertation, approval from the University of South Carolina and the local school district were received.

The entire action research process was an ethically sound endeavor, as I am seeking improvement to instruction to better teach students. Ethical teaching and inquiry involves carefully analyzing student work, assessing students on a routine basis, asking students questions about their learning, and closely observing students as they participate in the classroom environment (Dana & Yendol-Hoppey, 2014). I have included a more extensive discussion of the research design of the current action research study in Chapter 3: Methodology.

Significance and Limitations of the Study

This action research study was significant as it explored alternative pedagogical strategies to teach students complex scientific concepts while disrupting stereotypical gender norms present in an eighth-grade earth science classroom. The study utilized existing research in PBL, model-based instruction, and conceptual change theory in a science classroom. The results of the investigation could be used in part to shape future science instruction and research within science education and utilized to address systemic gender issues in science education.

My experience as a science teacher has led to my realization of the difficulty of teaching complex science concepts to students. Even when students correctly answer questions on a multiple-choice test, they often struggle to explain the concept in depth, or students may still have lingering misconceptions after science instruction has taken place. To bring students to a rich understanding of scientific phenomena, my use of traditional-lecture based instruction has fallen short. In addition, I have observed the marginalization of cisgender female students, as the cisgender male students tend to participate more during whole class discussions. Rarely do the cisgender female students raise their hands to be called on or participate willingly in whole-class discussion. Therefore, I implemented this action research study in an attempt to disrupt these stereotypical gender patterns while using PBL as a mechanism to bring conceptual change to all students.

The design of the study was created to reduce the limitations of this action research study. However, limitations were still present within the study. The results of the study are not generalizable to classrooms outside of this action research study. Because the investigation is an action research study, the sample of one teacher-researcher participant and 27 student-participants is a small sample size. The action research study took place over eight weeks, and the teacher-researcher meets with the student-participants in the classroom setting every other school day. In the future, future researchers could implement a similar study with a larger number of students in more classrooms over a longer period of time.

Summary and Conclusion

The current problem of practice involves difficulty I have experienced in teaching abstract space science concepts to a classroom of students in a rural school in the southeastern United States. In addition, I have observed the unintentional marginalization of cisgender female students, as these students tend to participate less during scientific class discussions. My research examines the impact of the PBL framework (McConnell et al., 2017) on the conceptual growth of all students while I attempted to disrupt the environment that may marginalize female students. Through this action research study, I have attempted to answer the following research questions: How does PBL impact the conceptual understanding of students in an earth science class? What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom?

Definition of Terms

Action Research – Action research is a cyclical and reflective research process where the researcher designs the study, collects data, analyzes data, and uses the data to create an action plan to implement solutions to the problem of practice (Herr & Anderson, 2005; Mertler, 2014)

Alternative Conception – important beliefs held by learners that may vary from an understanding based in scientific evidence (Chiappetta & Koballa, 2010)

Case Study – a strategy of conducting research “when the investigator has little control over events, and when the focus in on a contemporary phenomenon within some real-life context” (Yin, 1994, p. 1).

Conceptual Change – a process where people begin to see the world in different ways (Donovan & Bransford, 2005)

Constructivism – Constructivism is an educational theory where students are active in the learning process and do not simply acquire information directly from a teacher; the theory holds that “active students learn more than passive students” (Bodner, 1986, p. 874).

Ill-Structured Problem – a problem that has multiple correct answers and is typical of problems encountered in the real world outside of the classroom (Lee & Bae, 2007).

Mental Model – simplified cognitive representations of what we think we know” (Gilbert, 2011, p. ix).

Metacognition – the ability to be aware of one's own learning process through self-monitoring skills (Gijselaers, 1996)

Problem-Based Learning (PBL) – Problem-based learning is a pedagogy where the student is presented with a defined problem and the student acquires knowledge while developing solutions to the problem and develops problem-solving skills (Barrows & Tamblyn, 1980)

Qualitative Research – "uses narrative, descriptive approaches to data collection to understand the way things are and what the research means from the perspectives of the participants in the study" (Mills, 2018, p. 6)

Scientific Inquiry – Learning science as inquiry refers to the pedagogy or curriculum teachers use that describes how scientists actually do their work and a specific way of learning science where teachers guide students through the learning process (Yager & Akcay, 2010).

Scientific Model – a model supported by verifiable data that is testable, replicable, and falsifiable (Gilbert, 2011)

Traditional Lecture Methodology – The teacher imparts all knowledge necessary to understand a subject directly to the students (Dods, 1997)

Transfer Task – new and slightly different instance to apply what has been learned (McConnell et al., 2017)

Tutor – During the PBL process, the teacher serves the role of a "tutor," where the teacher acts as a guide or facilitator to the students as they research and design solutions to the given problem (Savin-Baden & Major, 2004)

Chapter 2:

Literature Review

In this chapter, I have provided a synthesis of the relevant literature to the problem of practice (PoP), a description of the theoretical framework used in the study, and a summary of the methodological approach and specific methods used in the study. This action research study involved the implementation of problem-based learning (PBL) with students in an eighth-grade earth science classroom in a rural middle school located upstate South Carolina while creating a more equitable environment for all students. The action research study employed Mertler's (2014) four-step action research cycle (see Appendix B).

Introduction

The purpose of the current action research study was to investigate my perceptions as the teacher-researcher while implementing PBL in a middle school science classroom. PBL is a student-centered pedagogical approach that is used to provide student participants the opportunity to ask questions, seek information, and design a solution to an ill-structured PBL problem scenario. During the PBL process, students are introduced to the problem before receiving academic instruction on content (Barrows, 1996; Barrows & Tamblyn, 1980; Torp & Sage, 1998; Savin-Baden & Major, 2004). McConnell, Parker, and Eberhardt (2017) modified a PBL framework; I used this framework in this action research study (see Appendix A). In addition, I have observed the impact of stereotypical gender norms present in the science classroom that may unintentionally marginalize female students. I have attempted to disrupt these gender norms and create an equitable classroom environment for all students through the action research process.

As the teacher-researcher, I have observed students tend to struggle in the incorporation of abstract science content into their mental schema. Throughout my experiences as an educator, I have noticed students often have difficulty in developing an evidence-based understanding of the motions of the sun, earth, and moon (SEM) and the observed phenomenon on earth, such as the appearance of the rising sun and moon, phases of the moon, and seasonal variation. The identification of the PoP led to the development of the following research questions:

1. How does PBL impact the conceptual understanding of students in an earth science class?
2. What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom?

My purpose in conducting this action research study was to describe my perceptions while leading a series of PBL scenarios in a southern, rural, eighth-grade science classroom. I have described student-created representations of their understanding of the SEM. I have also attempted to use a variety of discussion strategies in an attempt to disrupt gender norms present in my classroom. An action plan has been developed in conjunction with the student-participants to develop a model of PBL in eighth-grade science that will enable students to have a voice in their learning and make meaning for themselves within a Deweyan progressive education framework.

I chose the McConnell et al. (2017) PBL framework because this framework is appropriate for use in K–12 education (see Appendix A). Other PBL frameworks are specific to other individual content or designed specifically for medical instruction. For example, Barrows (1992) developed a model for use in medical schools where a facilitator is assigned to five or six students. Students receive a problem where a patient enters and provides and presents symptoms. The student must diagnose the patient and provide a rationale for the diagnosis and recommended treatment. This framework is not appropriate for an eighth-grade science classroom.

The current literature review analyzes related research on PBL instruction. There is a need within PBL research to include a focus on the actual process of PBL implementation, rather than comparing PBL to traditional lecture-based strategies (Dolmans, De Grave, Wolfhagen, & van der Vleuten, 2005). Hung, Bailey, and Jonassen (1993) noted how PBL is relatively new as a form of instruction. The researchers contended that their concerns for educators implementing PBL included the depth of the curriculum and student attitudes regarding the PBL process. Critics of PBL argue that PBL may limit students from being exposed to a broader array of content (p. 13). The researchers observed that teachers using PBL are likely to be highly aware and concerned with the time spent on the breadth and depth of the curriculum. Much of the research over PBL seems contradictory and has created tensions when educators attempt to implement PBL. Therefore, an in-depth analysis of the related research will contribute to a greater understanding of the issues that may be present while implementing PBL.

Historical Background

This action research study investigated my perceptions as the teacher-researcher while leading a series of PBL scenarios with a group of students in an eighth-grade earth science classroom. Relevant historical information includes an overview of the history of PBL, trends within science education, and local history that may impact this action research study. Researchers have identified issues in implementing PBL; therefore, I have included an overview of these issues. In addition to PBL, the other variable of this action research study includes gender norms impacting discussion and performance in science class and conceptual change; therefore, I have provided an overview of gender stereotypes and gender norms in science education.

History of PBL

PBL was developed in the 1960s at McMaster Medical School in Canada. Some medical professors thought traditional lectures did not provide learners with a relevant context for the content under study or its application in a clinical environment (Savery, 2006). State-funded public schools are evaluated based on student performance on high-stakes standardized testing. Teachers often use approaches like drill and practice and using practice tests to prepare students for these high-stakes tests. There is frequently not much time or initiative for teachers to use PBL as an instructional strategy. However, professional organizations, government agencies, and private industry are calling for a change in science education. The technological development of the 21st century has raised the bar for education; schools are challenged to develop students who can think critically, solve problems, and self-regulate their learning which are skills that are taught through the PBL process (Savery, 2006).

PBL draws from early philosophical notions dating as far back as the seventh century BC to the philosophy of the Milesians. Philosophers such as Thales, Anaximander, and Anaxagoras explored cosmological questions and advocated a questioning approach to learning. Ancient Greek philosophers in the fifth and fourth century BC acknowledge that the development of knowledge is personal. Socrates "believed that knowledge is unattainable … [and] wanted students to think harder and search to discover truth within themselves" (Savin-Baden & Major, 2004, p. 11). His reasoning led to the development of the Socratic dialogue, which uses questioning and probing—this strategy is inherent to PBL, where discussion is used to help students question their understanding when they confront a new problem.

McMaster Medical School was one of the first colleges to initiate a curriculum based on PBL pedagogy. The PBL curriculum of McMaster Medical School focused on creating simulations of patient problems like what a practicing physician may face (Savin-Baden & Major, 2004). Interest in the PBL method increased, and in the 1970s, several other medical schools began using the strategy (Boud & Feletti, 1991; Schwartz, Mennin, & Webb, 2001). PBL was initially used to train future doctors in their preparation to solve medical problems (Delisle, 1997). PBL has now expanded across many disciplines: health science, social work, engineering, architecture, business, law, economics, management, mathematics, education, introductory university science, secondary schools, and agriculture (Schwartz et al., 2001). PBL is still used widely in the medical education field, as it is "presently used in more than 60 medical schools worldwide and also in schools of dentistry, pharmacy, optometry and nursing" (Delisle, 1997, p. 6). PBL is now found within curriculum designed for K-12 students (Savery, 2006; Savin-Baden & Major, 2004). Throughout the years, PBL has grown worldwide and has become more flexible in structure than its original design (Savin-Baden & Major, 2004). PBL has been increasingly used in education and is now used as a tool to increase student achievement (Delisle, 1997).

Historical Trends in Science Education

Science education has undergone multiple reforms throughout the history of the United States. Recent educational history has "resulted in extensive use of standardized tests, standardized curricula, teacher's merit pay based on student test scores, and extensive data collected at state and federal levels of government" (Spring, 2014, p. 270). Bybee (2010a) argued that recent government reports on education often mention the importance of science and technology, but the reports seldom provide specific details on science and technology education; mathematics and literacy are the principal focus of the reports. Bybee (2010b) argued recent issues in science education result from:

> misdirected emphasis and undue attention on single initiatives that are largely political … most worrying is the contemporary emphasis on assessment, which does not account for the insights and possibilities that science teachers can bring to student learning. (p. 3)

Bybee (2010b) acknowledged how the current national agenda focuses on economic competitiveness and the development of a workforce to meet the needs of the 21st century. Businesses and industry have released numerous reports in recent years calling for educational reform. Bybee referred to concern from labor economists, who warn that children are not equipped with the skills needed to enter the middle class as industrial jobs have decreased and a need for a college degree has increased. Chiappetta and Koballa (2010) described the importance of developing an appreciation of "the interrelationship of science and technology" (p. 197) as the youth of today will experience rapid changes and developments in technological and scientific advancements in their lifetime and must understand the interconnectedness of science, technology, and society. Science may be more relevant to students if students are examining societal issues and applying scientific principles to these issues; students must be provided opportunities to "discuss their beliefs and values and to investigate and propose solutions to real-world problems" (p. 200). The current action research study employs a PBL that calls for students to use 21st-century skills such as adaptability, complex communication skills, non-routine problem-solving, self-management, and systems thinking (Bybee, 2010b).

Conceptual Change

Posner et al. (1982) defined conceptual change theory as making changes to "one's fundamental assumptions about the world" (p. 223). Conceptual change is a difficult undertaking as people often resist making changes to their understanding unless they become dissatisfied with their understanding of the concept under study and find or determine a plausible alternative. When a student encounters a new concept, the student must rely on prior knowledge to organize the new information. Sometimes the new information is assimilated into a prior schema of the learner. In other situations, the student must entirely replace or reorganize central prior understandings; this is known as accommodation and is a more rigorous form of conceptual change. Hewson (1992) argued, "learning may involve changing a person's conceptions in addition to adding new knowledge to what is already there" (p. 8). Therefore, conceptual change may involve the student understanding their way of thinking both before and after the learning process has taken place.

Gender Stereotypes

Sex-specific stereotypes within science and science education are not new (Chambers, 1983). Women are historically underrepresented in fields relating to STEM; however, there has been an increase in the number of women in these fields over the past 40 years. Despite the rise, science remains a male-dominated field and corresponds with a stereotype that associates males with science rather than associating people of all genders with science. Gender stereotypes have been found to exist across nations and have been shown to negatively impact females in STEM environments (Miller et al., 2014). Peer support and encouragement are correlated with an increase in girls' motivation in math and science (Leaper, Farkas, & Brown, 2011). The classroom environment can serve as a space for students of all genders to compete, collaborate, and learn from one another, and PBL may contribute to building a classroom culture that supports all learners (Ajai & Imoko, 2014).

Local Trends

In general, the school and district in which I teach values science education and the science program at the middle school level. Whenever I have a financial need as a teacher to supply my classroom, I can easily find funding through the school system to support this need. I am encouraged to try different strategies in my classroom outside the scope of traditional classroom instruction. However, several years before this action research study, the number of hours of instruction students receive in science class was drastically reduced. I currently teach approximately 200 students on an A/B schedule. I see the same students throughout the year. Each class is about 65 minutes in duration every other day. For example, if I meet with my A Day first block on Monday, I will have them in class for 65 minutes on Monday. I will not see the same group of students until Wednesday. Therefore, students receive approximately 165 minutes of science instruction per week and less if there are other school events, holidays, emergency drills, or other situations that may reduce the amount of time in science class.

Theoretical Base

The theoretical framework of this action research study is grounded in conceptual change theory and cognitive constructivism. I have described my perceptions while implementing PBL and scientific modeling with a class of eighth-grade students. I have attempted to disrupt typical gender norms present in an eighth-grade class; therefore, the intersectionality is relevant to the theoretical base of this action research study.

Conceptual Change Theory

Conceptual change theory is relevant to this action research study as student preconceptions and misconceptions were used to guide the instructional process. Students enter the classroom with their ideas about the causes of everyday phenomena; the preconceptions may or may not align with an evidence-based scientific understanding of the phenomenon. Science instruction often fails to leave students with an evidence-based understanding as students often walk away with the beliefs they were grounded in before instruction. Sometimes, science instruction can reinforce the misconceptions students believe before instruction (Chiappetta & Koballa, 2010). Student alternative conceptions are argued to exist before, during, and after science instruction. Instruction must focus on the conceptions of students throughout the instructional process. Student conceptions may vary wildly across the classroom as students have a wide variety of different experiences and backgrounds. It is argued that learning science "is not a matter of simply adding information or replacing existing information" (p. 167). After instruction has taken place, students may fail to leave the class with an evidence-based science understanding. Teachers should address what students already know before instruction and urge students to reflect on their ideas and believes that they possess regarding a particular science concept. The process of working through wrong ideas or a lack of ideas is an essential aspect for bringing conceptual change within the student (McConnell et al., 2017).

Two components are imperative to fostering conceptual change: the conditions to be met or not met for a person to experience conceptual change and the conceptual ecology that provides the context and gives meaning to the conceptual change. According to Hewson (1992), the more conditions that a person's understanding meets, the higher the status of the conceptual understanding of the individual. The conceptual ecology of an individual "provides the context in which the conceptual change occurs, that influences the change, and gives it meaning" (p. 8). The conceptual ecology consists of a variety of different types of knowledge including epistemological commitments and metaphysical beliefs about the world.

There are essential factors that must be fulfilled to support accommodation of new knowledge. The learner must be dissatisfied with his existing preconceptions. Individuals are less likely to make changes in their conceptual understanding unless they believe their understanding is faulty (Posner et al., 1982). The new way of understanding must make sense to the individual and be understandable or intelligible, meaning the person knows what the concept means. The new idea also should extend into other areas of future inquiry, and the individual must find the concept useful (Hewson, 1992; Posner et al., 1982). Hewson (1992) argued that if the concept meets these factors, then "learning proceeds without difficulty" (p. 8).

It is important to note that there are differences in how some view the actual meaning of conceptual change. Hewson (1992) discussed how some might believe that conceptual change is when a student holds a particular view that is different than a scientific view of the phenomenon. Conceptual change is not necessarily the act of a person changing her mind about her views of the world. Instead, “exchange” may be a better characteristic because the prior understanding does not necessarily disappear, as students will often remember both views and understand how one may or may not make more sense.

Cognitive Constructivism

Critics argue conceptual change theory does not include the motivation, values, and interests of the learner or the social components of learning (Pintrich, Marx, & Boyle, 1993). Therefore, cognitive constructivist theory is relevant to my teaching practice and the theoretical framework as I work to teach holistically and engage all learners. Cognitive science can provide insight in ways for science teachers to engage students actively in the learning process and a theoretical framework for how learners can encode short-term and sensory memory into long-term memory (Driscoll, 2005; Harasim, 2012; Mergel, 1998). Cognitive psychologists recommend teachers think of learning as an active process where students engage with ideas, instead of a passive process where students passively receive information (Chiappetta & Koballa, 2010). The use of cognitivist theory within education stems from the field of cognitive psychology (Driscoll, 2005). Within the cognitivist perspective, learning is believed to occur through “complex cognitive processes such as thinking, problem-solving, language, concept formation, and information processing” (Ertmer & Newby, 2008, p. 50). These processes serve as the basis for learning. Mental processing is an essential aspect of the learning process within cognitivism. Following World War II, computers emerged within the technological world and provided a concrete framework for understanding the process of thinking, learning, memory, and perception. This metaphor of the brain as a computer led to the development of the idea of information processing. Learning occurs as the student receives information from the outside environment. The information is processed and stored in the memory. The output of the learner is a newly learned ability (Driscoll, 2005).

Many proponents of PBL argue that components of the strategy fall under constructivist educational theory (Savery & Duffey, 2001; Savin & Major, 2004; Torp & Sage, 1998). Constructivists hold "that knowledge is not an absolute, but is rather constructed by the learning based on previous knowledge and overall views of the world" (Savin & Major, 2004, p. 29). The student must be actively involved in the learning process to be able to select and interpret information. Learning occurs when there is cognitive conflict and through the evaluation of one's understanding. Savery and Duffey (2001) characterized constructivism from three positions:

1. "Understanding is in our interactions with the environment" (p. 1).
2. "Cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learned" (p. 2).
3. "Knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings" (p. 2).

Savery and Duffey (2001) argued that the foundation of constructivism is the belief that understanding is within the learning environment. How the student learns content is learned is directly related to what the student learns. The learner must have a purpose for being in the learning environment. The learning environment is critical to the development of knowledge. It is essential that students work in collaborative groups so each can test their understanding and examine the knowledge of others. This process serves as a method of deepening knowledge of a topic of study.

Problem-Based Learning

During PBL, students work in teams and construct knowledge for themselves as they gain experience with the PBL problem scenario. Students work collaboratively while solving a complex problem to build understanding, thus the learning that occurs is considered student-centered (Barrows, 1986, 1996). Proponents of PBL believe that effective learning takes place when students are actively involved in the learning process and are learning content within the context of how it can be used (Boud & Feletti, 1991). During PBL, students are expected to think critically and creatively as well as monitor their understanding (Savery & Duffey, 2001). PBL is relevant to the middle school classroom, as middle school students are often not interested in academics but sometimes become more engaged when the student knows a problem can affect their school or community (Torp & Sage, 1998). Savery and Duffey (2001) argued all learning activities should be anchored to a more significant task or problem, as humans "learn in order to be able to function more effectively in our world" (p. 3).

PBL relates the curriculum to the individual lives of the students. Delisle (1997) noted that students are more motivated to understand and remember information if it connects to their lives. Student choice is an important part of the PBL process; PBL requires students to determine how and what they will learn. Problems used in PBL should be as close to real-life situations as possible, and students should be allowed a degree of freedom and choice when designing a solution to the PBL problem (Savin-Baden & Major, 2004).

Scientific Modeling

Model-based instruction (MBI) can be used in conjunction with PBL, as students often work collaboratively to develop a model as the solution to the PBL problem (McConnell et al., 2017). Students develop informal mental models to represent phenomenon from a very young age. However, developing an evidence-based scientific mental model is more demanding. During scientific modeling, students must "articulate their model as a set of propositions that can be confirmed or disconfirmed" (Donovan & Bransford, 2005, p. 519). Through MBI, the teacher introduces students to a variety of scientific norms: "argumentation concerning data, explanations, causal models, and their relationships" (p. 519).

Using models and model-based instruction requires thoughtful and active participation by students within the classroom. Students must be aware of their knowledge and reasoning. It is imperative for teachers to be mindful of preconceptions in an attempt to foster conceptual change. The teachers must give students ample opportunities to make their understanding public and visible to teachers and therefore should be able to articulate their process of arriving at a solution (Donovan & Bransford, 2005). Students often fail to grasp the use of models as a conceptual structure representing a phenomenon and believe model to be a small replica of a phenomenon. Instead, they should be guided to understanding "the conceptual nature of scientific models and learn how to evaluate them for consistency with other ideas" (p. 519).

Intersectionality

Because this action research study explores gender bias in the science classroom, intersectionality is a critical aspect of this action research study. Gilligan (1991, as cited in American Association of University Women, 2002) referenced how "developmental psychologists theorize that while boys are most physiologically at risk in childhood, for girls the time of greatest risk is adolescence" (p. 243). Girls may respond to societal pressures by giving up their voice, abandoning their true selves, feeling worthless, or disassociating institutions that do not give them value. For example, Gilligan (1992, as cited in American Association of University Women, 2002) tracked girls through elementary schools into their adolescent grades and found that girls that were courageous, resilient, and willful in the classroom began adding into their speech the phrase, "I don't know." The American Association of University Women (2002) concluded that teachers must be aware of the different ways girls negotiate school because gender and the way society interprets genders are critical factors that influence adolescent girls.

The science classroom contains a community of learners working together. When using PBL, the classroom must be a structure where all students are expected to participate. Discourse must occur throughout the learning process and should be "anchored in norms of argumentation that reflect scientific practice" (Donovan & Bransford, 2005, p. 559). Therefore, the teacher must establish expectations for all students for classroom participation. I have noticed in my classroom how young women often fail to speak up voluntarily to share their preformed ideas about scientific concepts. Brown (2002) argued common perceptions of girls in the classroom include "images of cooperation, compliance, polite silence, or perhaps, invisibility" (p. 204). Therefore, a variety of forms of communication and discussion techniques were used to foster participation from all classroom members. Cartier, Smith, Stein, and Ross (2013) recommended a classroom environment where the independent thinking of all students is valued and is "held accountable to disciplinary norms" (p. 88) during classroom discussion. Disciplinary norms during this action research study included the practice of making students aware that they should encourage participation from one another within the group and the promotion of participation from all students by the teacher-researcher.

Issues in Problem-Based Learning

Mark Albanese (2009), a leading researcher of PBL in medical education, noted the difficulty of studying any curriculum intervention. He observed:

> Anyone attempting to demonstrate the superiority of one medical curriculum over another is faced with a fairly daunting task. A curriculum is such a complex web of interlaced learning experiences that attributing change to any one component is perilous. (p. 199)

There are countless variables in a real-world study of PBL that can impact the results of PBL research. In addition to the difficulties of multiple variables in PBL studies, many researchers argue for changes in the study of PBL curriculum. For example, Dolmans, De Grave, Wolfhagen, and van der Vleuten (2005) explained that the type of research reviews over PBL research differs substantially between the research conducted in the early 1990s and the research conducted since 2000. In general, the literature reviews of the early 1990s found students and faculty were "highly satisfied with PBL … [and] PBL stimulates students towards constructive, collaborative and self-directed learning" (p. 737). In recent PBL research, a trend has emerged where research studies compare PBL to traditional curriculum. Debates on the effectiveness of PBL have emerged. The reviews of studies conducted since 2000 have been criticized "because of their strictness in including only studies in which conventional and PBL curricula are compared" (Dolmans et al., 2005, p. 737). Recent reviews have these studies evaluate the final summative goals of PBL, and researchers are not investigating the theoretical foundations of PBL.

Norman and Schmidt (1992) conducted a meta-analysis of PBL research and determined several advantages of PBL instruction. The researchers found PBL may increase retention of knowledge learned, PBL may contribute to the transfer of ideas to new problems, increases students interest in the curriculum, and appears to improve the self-directed learning ability of the student. The authors acknowledged that "to date there is no evidence indicating that one curriculum or another, problem-based or otherwise, is able to enhance students' problem solving skills" (p. 58). The authors argued that the brain is not to be filled with facts, not to be viewed as a "leaky vessel to be filled with facts at a high enough rate that they all flow out" (p. 559), but instead students learn in a more meaningful way when working through a problem and acquiring knowledge through self-directed learning.

Albanese and Mitchell (1993) conducted an important literature review in the early 1990s, finding students are highly satisfied with PBL curriculum and believe they are better prepared to learn independently and engage in self-directed study. Albanese and Mitchell also determined teachers were satisfied with using PBL as a teaching strategy. The report notes that there is confusion over the meaning of PBL. The review determined that in comparison to lecture-based instruction, PBLs are more nurturing and enjoyable, PBL graduates perform at the same level or better on evaluations, and faculty tend to enjoy teaching more though PBL. However, there are instances where PBL graduates score lower on examinations than students from a lecture-based curriculum. PBL graduates sometimes view themselves as less prepared than students who received traditional instruction. There is also the concern of study design used in PBL research. Therefore, the authors recommended caution when considering switching to curriculum entirely based on PBL framework.

Charlin, Mann, and Hansen (1998) used PBL literature to outline a framework of using PBL as an educational strategy and identify the main dimensions of PBL. The authors believed that if a PBL framework is used systematically in the literature, then confidence will be increased in future studies and “our understanding of PBL and its effects will be improved” (p. 329). The researchers recommended future PBL studies include a discussion of the PBL framework used in the study.

A heavily cited secondary source is a literature review conducted by Norman and Schmidt (2000). The overview highlights the psychology of memory and argues that PBL aligns with learning and memory theory. PBL is thought to lead to long-term retention of material. Students might learn less material initially but are thought to process the information more extensively.

Haney, Wang, Keil, and Zoffel (2007) examined the beliefs and classroom practices of teachers during a professional development program that provided teachers experience developing, implementing and revising PBL curriculum that focuses on environmental health issues on a local scale. The PBLs used in the study were interdisciplinary: The authors observe the educational system does not value integrated curriculum as current public education in the United States is swinging back to “standards-driven, discipline-based curricula” (p. 32). Essentially, given the current structure of public education, the model employed in this study would be difficult to implement in a typical public school realistically. The study called for teachers to collaborate and network with each other and “with relevant community agencies, local scientists, and university environmental health and education faculty” (p. 26). The researchers did not include a discussion of the individual PBL projects used by each teacher; however, the authors recognize the value of using PBL to address real-world local environmental issues.

Wong and Day (2008) conducted a quantitative study comparing PBL to lecture-based learning in Hong Kong to determine the effect of the treatment on the science achievement of secondary students. The study used two groups where one group received PBL instruction, and the other group received lecture-based learning instruction. The students answered multiple-choice questions and short answer response items. The study found that PBL was at least as effective as lecture and could be an effective strategy for achieving learning goals in secondary science education for students in Hong Kong.

Strobel and van Barneveld (2009) conducted a meta-synthesis of studies comparing PBL to conventional classrooms. The researchers applied statistical methods to analyze individual studies. The researchers found that PBL is more effective than traditional learning approaches in training the "competent and skilled practitioner and to promote long-term retention of knowledge and skills acquired during the learning experience or training session" (Strobel & van Barneveld, 2009, p. 55). The authors also recommend that PBL research should move away from evaluating the effectiveness of PBL in comparison to traditional lecture; instead research should focus on differences within the PBL process including support structures, scaffolding, coaching, and modeling strategies for the successful facilitation of PBL (as cited in Albanese and Dast, 2014, p. 243).

Hung (2011) recognized how many studies in PBL research do not focus on the process of PBL implementation; instead, the studies look at the outcome of student score on assessments. This is problematic because when a teacher uses an instructional technique in a classroom, there are numerous variables, both known and unknown, that could affect the final learning of students. Hung argued that studies use different PBL models to fit their educational needs, therefore determining the overall effectiveness of PBL virtually impossible to achieve. Therefore, researchers must examine the process of implementing PBL in an attempt to describe how they came to their results.

Gallagher and Gallagher (2013) conducted a study using PBL to explore unseen academic potential. The researchers argued that the needs of low-income students with great academic potential are often ignored, resulting in a "substantial loss of human potential" (p. 112). Wyner, Bridgeland, and Dijulio (2007, as cited in Gallagher & Gallagher, 2013) found that around 44% low-income students who identify as high achieving in first grade are no longer high achieving in fifth grade. Gallagher and Gallagher argued that the underachievement of low-income students is that "low-income classrooms are not designed for high-achievers" (p. 113). These classrooms often are aligned heavily with accountability tests, overly simplistic, and predominantly fact and memorization based. The Gallagher and Gallagher study had a sample size of 271 sixth-grade students in 13 classrooms. The students were taught using two different PBL units. Following the completion of the PBL units, the teachers identified students who excelled during the PBL experience. The study suggested that "a well-designed, engaging curriculum such as PBL can create learning context that encourages more students to reveal academic potential" (p. 111).

Albanese and Dast (2014) conducted a literature review of 20 reviews of research conducted since 1990. The authors note the difficulties of determining whether PBL creates the changes in learners that it intends, which is to create "self-directed learners who have a deeper knowledge of their discipline" (p. 239). Studies have been inconclusive of the benefit of PBL for the creation of self-directed learners.

Methodology

The current study used an action research methodology in an attempt to describe my perceptions as the teacher-researcher while leading a series of PBL scenarios in an actual eighth-grade earth science classroom. Action research is a powerful tool that can be used by educators to address local problems and find immediate solutions (Mertler, 2014). Action research calls for the specification of a problem in the classroom and focused research to better understand the problem (Dana & Yendol-Hoppey, 2014). The action research process is known to "untangle some of the complexities that occur in the profession, raise teachers' voices in discussions of educational reform, and ultimately transform assumptions about the teaching profession itself" (p. 5). The process of action research will serve as an inquiry into my practice as a science teacher (Dana & Yendol-Hoppey, 2014; Mertler, 2014). Action research can bridge the gap between theory and practice. Often, traditional research is used as a technique to develop educational theories. There is often a gap between the findings of traditional research and the practices used by teachers in actual classrooms (Mertler, 2014). As the teacher-researcher, I evaluated the impact of PBL pedagogy in my classroom through Mertler's four-step action research cycle.

Pinar (2013) argued against the scientific curriculum building of the traditionalist reform movement, as this movement is occurring outside the field of education and has been used to maintain traditional societal values. Pinar argues that many of the researchers involved in developing curriculum "view themselves as primarily psychologist, philosophers, or sociologists with 'research interests' in schools and education-related matters" (p. 152). Therefore, Pinar believes, "the education field has lost whatever … intellectual autonomy it possessed in earlier years, and now is nearly tantamount to a colony of superior, imperialistic powers" (p. 152). Freire (2013) passionately argued against scientific curriculum making as he accuses the

> investigator who, in the name of scientific objectivity, transforms the organic into something inorganic, that is becoming into what is, life into death, is a man who fears change … He does want to study change—but in order to stop it, not in order to stimulate or deepen it (p. 164).

Action research performed by in-practice classroom teachers is an appropriate way to integrate research into the teaching field. Because I identified a problem of practice in my classroom, solutions to the problem of practices are being developed in the field rather than from a higher authority.

Recent research found in PBL literature frequently uses controlled quantitative studies where PBL curriculum is compared with conventional curriculum methods like lecture-based discussion (Dolmans et al., 2005). Norman and Schmidt (2000) argued that this type of experimentation is useless because the educational environment is complex and full of multiple variables—success or failure cannot be determined based on the intervention. Dolmans et al. (2005) argued what "is needed is research that bridges theory and practice and extends knowledge about developing and improving PBL in everyday practice" (p. 739). Primarily, research is needed that applies the theories behind PBL in a way intertwines the theories with the practice of teaching.

The current action research study was in the form of a qualitative action research study. Qualitative research requires extensive involvement from the researcher, as the researcher immerses herself in the research process. The data collected were descriptive, and the research problem and methods evolve as the study progresses. Data organization relied on the categorization of data and organized into patterns as I attempted to create a description of the problem under study (Mills, 2018). I collected data as I immersed myself as the teacher-researcher in an intrinsic case study to determine the impact of problem-based learning on conceptual change and attempt to disrupt gender norms present in an eighth-grade earth science classroom.

An intrinsic case study is appropriate to use for when the researcher wants to know "more about a particular individual, group, event, or organization" (Hancock & Algozzine, 2006, p. 32). In an intrinsic case study, researchers are often not interested in examining or building theories or in generalizing findings to a larger population. Case study research is a method to investigate a particular topic by following a set of predetermined procedures. The case must be defined and is the primary unit of analysis (Yin, 1994). In this action research study, the unit of analysis included me as the teacher-researcher and the 27 student-participants who engaged in a series of PBL learning scenarios.

Related Research Studies

There is a significant amount of research on using PBL with medical students, but there is a lack of experimental evidence of the effect of PBL in K–12 education. McConnell (2002) conducted an action research study analyzing PBL with a group of learners who were professional people working in e-learning groups where each group embarks on a learning journey without an "exact detail of how they should work together or what the outcomes of their learning should be" (p. 60). The experimental design was naturalistic instead of experimental, as the researcher used observation, ethnography, textual analysis, and in-depth interviews. The groups in the study were the natural groups of e-learners in the course. The data collected were subjected to a grounded theory approach, as "the researcher is not bringing existing theory to the analysis of data, but rather developing theory inductively from the body of data itself. The theory must grow out of the data and be ground in the data" (p. 65). Throughout the research process, the researcher made notes through a process of progressive processing where important and relevant issues became apparent. The notes served as interesting issues for investigation and represent potential categories. The categories emerged through the process, and the researcher attempted "to find evidence that might support or refute each category being included in the final set of categories" (p. 65). Over time, the categories were modified based on analysis of the transcripts to create the final explanatory categories of the study. This study is relevant to the current action research study, as I will be collecting data in the form of the qualitative case study. Data will be analyzed as patterns and themes emerge throughout the action research study.

Lee and Bae (2008) conducted a study in an eighth-grade science class using PBL to study volcanoes. The researchers found that group dynamics and teacher questioning strategies guided the learning of the students. Students collaboratively gathered evidence, and much of the evidence was required to be more developed than merely listing terms or facts. Researchers observed that the teachers tended to fall back into the traditional role of focusing on facts about volcanoes. Lee and Bae argued that students should work with "ill-structured" problems as well-structured problems with a definite answer give students a limited change to apply knowledge that they have learned in class and fewer opportunities to explain natural phenomenon or make decisions about real-life scientific problems. Problems encountered in the real world often have more than one correct answer. The authors argued that the PBL strategy provides students with "opportunities to be exposed to real-world situations … absorb new ideas in various disciplines, perceive patterns, and work actively and collaboratively" (p. 656). The PBL used in the study called for students to explore and research real volcanoes in Hawaii and Washington state and to more broadly understand the role of volcanoes and earthquakes in plate tectonics. During the study, the teachers expressed concern about the "pressure to cover all the relevant scientific concepts in the textbook. This tension seemed to bring about the tendency to slip into a traditional role" (p. 675). The teachers were concerned about the number of scientific ideas understood by their students and whether students were correctly interpreting and understanding their evidence. The researchers concluded that teacher-educators should

> pay more attention to teachers' practical knowledge in the design and implementation of the PBL approach, rather than forcing them to accept only the ideals of the structured PBL strategy or cookbook types of manuals for the PBL approach (p. 675).

Lawless and Brown (2015) conducted a study using PBL simulations for middle school students in a game format as students played the role of an international science advisor. The study used a large sample size of 535 middle school students. The two simulations used included water resources and climate change. The researchers found that the students in the study had a positive change in scientific knowledge over content included in the simulations. The researchers used the GlobalEd 2 curriculum, which employs interdisciplinary content to develop science and writing skills through PBL. Students were determined successful in the program is the researchers found the students were understanding "the important scientific principles related to the presented simulation issues … [and] recognize how these issues relate to the countries participating in the simulation" (p. 182).

Wirkala and Kuhn (2011) conducted a controlled PBL with three classes of sixth-grade students at an urban middle school. The manipulated variable was the form of instruction—either PBL or lecture-based instruction. The study found that PBL increased long-term retention of the material and ability to apply the new material over the lecture/discussion method.

Liu et al. (2014) conducted a study on the use of PBL with middle school students; the PBL was in a multimedia-enriched environment where students used the platform Alien Rescue to teach space science. During the PBL, students took responsibility for their learning while working in collaborative groups to solve a complex and ill-structured problem. The students used a notebook during the experience to organize and store information. Students were required to identify important information and make comparisons to solve the central PBL problem. The notebook tool within the program also provided scaffolding support to aid students in the problem-solving process. As students gain experience in the PBL, the level of scaffolding within the notebook tool decreases.

Tawfik and Trueman (2015) conducted a study that measured the effects of case libraries in a PBL STEM course in introductory biology. The PBL experience employed a case study that students can relate to previous experiences. The researchers assigned ninety-five students to either the group with the case library or the group without a case library. Case libraries are a database of cases used to support the PBL process. The PBL used in this experiment was developed using Hung's (2006) problem design model (as cited in Tawfik & Trueman, 2015). The learning of students was measured using a pretest-posttest experimental design. The results of the experiment provide evidence that

PBL is more effective when students are provided scaffolding during their learning experience.

Cerezo (2004) discussed the use of PBL as a strategy to meet the needs of at-risk females in middle school math and science classrooms. Cerezo argued that it has become more challenging to engage female students in math and science. PBL calls for students to become independent learners where they work in small groups, collaborate to solve a problem, refine and organize their knowledge, and eventually present a solution to their problem. Cerezo analyzed the impact of PBL using a case study investigation to determine the details of the perceptions of those involved in the study. Cerezo found that many students noticed changes in their performances during the study and self-efficacy increased. Some students experienced increases in their confidence and felt that PBL impacted their performance.

Han, Capraro, and Capraro (2015) conducted a study to measure the effect of a STEM PBL on the performance of students of varying abilities and socioeconomic status (SES). The study found that PBL increased student problem-solving ability and increased achievement of lower performing students. However, the study found that STEM PBL had a negative effect on students of a lower SES. The researchers recommend PBL instructors work to identify components of the PBL that might lead to poor achievement of students of a lower SES.

Sundberg, Kennedy, and Odell (2013) designed workshops for teachers to use PBL as a strategy to address local and global climate topics with their students. The authors argued that the United States is lagging behind other countries in the preparation of teachers and students in understanding climate science. The PBL on climate science calls for students and teachers "to be critical data consumers, innovative thinkers, and adept at interactive, cross-cultural communications" (p. 123). Teachers have discussed a barrier in climate science education as there is a gap "between the scientific community and the general public" (p. 124) on climate science.

Conclusion

In conclusion, Chapter 2 provides an overview of the historical background of science education, PBL, conceptual change, gender stereotypes within science education, and local issues that may impact the action research study. The theoretical base of the action research study includes conceptual change theory, PBL, MBI, and intersectionality. Chapter 2 elaborates on the issues found in the literature regarding PBL and includes a discussion of the methodology and related research studies. The methodology of the current action research study is explained in more detail in Chapter 3: Methodology.

Chapter 3:

Methodology

In this chapter, I have provided a discussion of action research and intrinsic qualitative case study research, as these were the approaches taken to answer the research questions. I then described the specific steps of enactment for the intervention, the methods of data collection, and the methods of data analysis that I employed in the study. The chapter concludes with a description of how I developed an implementation plan.

The identified problem of practice (PoP) for the present action research involved the difficulty I experience as a teacher attempting to bring eighth-grade students to an evidence-based conceptual understanding of abstract science concepts. When I have used lecture-based instruction in the past, students struggle to connect science content to their personal experiences outside of the classroom. In addition, I have observed the unintentional marginalization of female students in the science classroom, as this environment has traditionally favored male students. The purpose of this action research study was to describe the perceptions of the teacher-researcher while conducting a series of problem-based learning (PBL) scenarios in an eighth-grade earth and space science classroom while attempting to disrupt stereotypical gender norms that are pervasive in science and science education. The guiding questions for this action research study were: How does PBL impact the conceptual understanding of eighth-grade students in an earth science class? What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? This action research provided an opportunity for me to better understand my perceptions as a teacher new to the PBL framework; therefore, participatory action research in the form of a qualitative intrinsic case study was the most appropriate methodology to answer the present research questions.

The middle school will be referred to by the pseudonym Shannon Middle School (SMS). As the teacher-researcher, I have described my perceptions while implementing a series of PBL scenarios in an eighth-grade earth science classroom. I have described the impact of the PBL framework (McConnell et al., 2017) on the conceptual understanding of the student-participants. I have collected qualitative data continuously throughout the action research study to capture a holistic understanding of PBL in an eighth-grade science classroom. Through the use of a holistic perspective, I have attempted to understand the entire phenomenon as a complex and interconnected system (Fraenkel et al., 2015). Qualitative data provides a thorough and detailed description of the phenomenon and promotes an in-depth inquiry into the studied phenomenon (Yin, 1994).

Rationale for Selected Methodology

Action research is the most appropriate methodology for addressing the current PoP. The goal of the action research process is to address problems on a local scale in an attempt to find immediate solutions. In action research, the researcher immerses himself within the research process. The researcher often serves as a reflective practitioner attempting to solve a problem and to become a more effective educator through the action research process. Educators may undergo action research to gather information about their schools, their teaching practice, or how their students learn. Because of the locality of the study, the results of action research are not generalizable to a larger population. Traditional research may often have greater generalizability. However, traditional educational research is generally written in a way that does not fit with the daily needs of teachers. Therefore, teachers may not find formal or applied academic research very helpful for addressing problems they may routinely encounter. There is a great benefit on a local scale for using action research to improve education within a community (Mertler, 2014). Mertler's four-step action research cycle was used to address the current PoP (see Appendix B).

The design of the action research study was a qualitative intrinsic case study (Mills, 2018). A case study explores one individual student, classroom, school or program (Fraenkel et al., 2015). A case study is appropriate for studying and exploring events, processes, and activities. There are many variations of case studies; an intrinsic case study is a case study where the researcher is interested in learning more about a specific individual or situation. The goal in an intrinsic case study is for the researcher to understand the case under study in great depth by gaining insight into the inner workings of the specific case (Creswell, 2014). As the teacher-researcher, my interest was in improving my teaching practice to serve my students on a local scale. I have attempted to gain a holistic understanding of the underpinnings of teaching the sun-earth-moon (SEM) system to students in my classroom. I have also tried to disrupt stereotypical gender norms present in my classroom and create a more equitable science classroom for all students. Because of the nature of the PoP, a qualitative intrinsic case study was appropriate for this action research study.

Research Context

The current action research study investigated the implementation of PBL in an eighth-grade earth science classroom at SMS with a class of heterogeneously grouped students. The class of student-participants includes 27 students between the ages of 13 and 14. Thirteen of the students are female; fourteen of the students are male. Eighteen percent of the student-participants receive free or reduced lunch, which is lower than average in comparison to the school population. One student has a 504 instructional plan. All of the students are fluent English speakers. The majority of the students are White, three students are Hispanic, and one student is Black. All of the students in the study are in either honors English or honors Algebra, which are high-school-level courses. The setting of the research study is a natural setting as the teacher-researcher is collecting data where the student-participants experience the current problem of practice under study (Creswell, 2014).

SMS is a middle school in the southeastern United States serving approximately 750 students in Grades 6–8. About 40% of the students at SMS participate in Medicaid, Supplemental Nutrition Assistance Program, Temporary Assistance for Needy Families, or are homeless, foster, or migrant students; these measures indicate the student poverty index. SMS has an attendance rate of 95.6% for its students. Approximately one-third of students in Grades 7 and 8 are enrolled in high-school-level classes or are in gifted and talented programs. Around 13% of students enrolled at SMS have disabilities. Each student at SMS has school-assigned iPad allowing 1:1 technology; wireless Internet is available throughout the school and for use with the school-approved device. The students at SMS are generally motivated to perform well in academics; SMS consistently scores "excellent" on the South Carolina State Report Card. SMS is one of three middle schools in a school district located in the southeastern United States. The school district serves 9,743 students across 14 schools: one primary school, seven elementary schools, three middle schools, and three high schools. The school district prides itself on its high graduation rate: The 2015–2016 school year held a graduation rate of 92.3%, much higher than the state graduation rate of 83.9%.

As the teacher-researcher, I was actively involved in the action research study, as I served as a participant in the sample. The unit of analysis for this case study is me as the teacher-researcher and the 27 student participants. The unit of analysis defines and sets the case study (Yin, 1994). Because the class of 27 students is inseparable from my perceptions as a teacher-researcher, they are a part of the unit of analysis. This action research study explored my perceptions as I implemented a series of PBL scenarios with eighth-grade students as a new PBL tutor. Therefore, my background and experiences are factors to be considered by others interested in the results of the action research study. I have taught middle-level science for seven years. My undergraduate degree was in Forestry, which has given me a science background before becoming a science teacher. My graduate degree was in science education. Before this study, I had only used PBL as a learning strategy one time. I have used similar approaches, such as project-based learning, teaching through inquiry, and problem-solving activities. I occasionally use lecture-based instruction when time is limited or if I have not found an instructional strategy to fit the content, but I believe student-centered approaches to science education are the most appropriate for meaningful learning experiences. While I began this action research study as an inexperienced PBL tutor, I enjoy trying different styles of teaching and developing curriculum, and I was very excited to try PBL with my students.

Because I implemented PBL with a class of eighth-grade students, their progress and experiences within the curriculum were used to provide insight into my perceptions as a new PBL tutor. The sample from this study came from students in an eighth-grade earth science class at SMS. During the action research study, I was the teacher of eight earth and space science classes. I selected one of the eight classes for the current action research study. All of the 27 students in this class were a part of the action research study and included within the unit of the case. Throughout the study, I selected students using a maximal variation approach to showcase different perspectives or levels of understanding. Because the sample size consisted of a small number of students (n = 27), selecting students randomly from the group of 27 students would likely not representative of the entire class; therefore, a maximal variation approach was used for certain parts of data collection (Fraenkel et al., 2015).

I selected the sample of cisgender female students for the focus group interviews from the larger class of 27 students using a maximal variation sample; this type of sample is "selected to represent a diversity of perspectives or characteristics" (Fraenkel et al., 2015, p. 434). I selected each student based on teacher observation of how much each cisgender female student speaks during class. I attempted to obtain a variety of students to offer different perspectives. Therefore, I selected both students who tend to speak up and students who tend to stay quiet during instruction. The sample chosen for the video reflections were also selected from a maximal variation sample, as I described artifacts created by three cisgender male students who displayed varying levels of understanding of the SEM system and artifacts created by three cisgender female students who displayed varying levels of understanding of the SEM system.

I used convenience sampling for the action research study because it is impossible to generate a random sample in this situation. Random sampling is virtually impossible to achieve in a typical school environment. Because of these limitations, action research is not generalizable to a larger population but can still improve educational practice by exploring pedagogy and applying research findings from other studies within the classroom (Mertler, 2014; Fraenkel et al., 2015). When random sampling is not possible, Fraenkel, Wallen, and Hyun (2015) recommended that the researcher describe the population as thoroughly as possible so that others interested in the action research study can decide which findings may apply to a different situation.

Research Methods

I used Mertler's (2014) cyclical four-step process for the design of this action research study. As the teacher-researcher, I was a full participant, as I am part of the group and also collecting data on the group. The four stages of action research are the (a) planning stage, (b) acting stage, (c) developing stage, and (d) reflecting stage. During the planning stage, I identified and limited the topic, gathered information, reviewed literature, and developed a research plan. During the acting stage, I collected and analyzed data. During the developing stage, I developed an action plan. During the reflecting stage, I communicated the results and reflected on the process. Throughout the entire action research process, I engaged in systematic reflection. The action research process does not have a definite ending. Following the end of the first cycle, the action research process will resume in the following year with the next group of students.

Planning Phase

My experiences as an earth science teacher and discussions with colleagues led to the development of the current PoP. I have routinely conducted informal surveys with my students; many of the students appear to enjoy learning through pedagogical strategies other than the traditional lecture-based methodology. I generally use a variety of strategies to teach the content, but I have struggled to guide all of my students to an evidence-based understanding of the SEM system. When I revisit the SEM throughout the year, many students have little or no memory of the content standards on SEM system. Gijselaers (1996) argued that learning through lecture is of little use in helping students develop a long-term understanding of content. This PoP led to the development of my research questions.

I have also noticed in my classroom that the young cisgender women in the class often do not answer questions and do not regularly volunteer to participate in class discussions. The eighth-grade cisgender males tend to typically dominate the classroom, as they are more frequently the students who volunteer to answer questions or participate in activities. Bazzul and Sykes (2011) argued that "schools are often involved in propagating oppressions related to sex/gender and sexuality" (p. 269). As an educator, it is important to create an inclusive classroom for all students, regardless of sex and gender identities. Therefore, I hope to disrupt typical gender norms by creating an environment where all students are active participants in the learning process. Following the development of the research focus, I created a research plan where I designed a study to answer the research question.

Acting Phase

As the teacher-researcher serving as both the researcher and the focus of the case study, I collected a variety of data in an attempt to gain an understanding of my experiences while leading a series of PBL scenarios as a new PBL tutor. I have attempted to answer the questions: How does PBL impact the conceptual understanding of students in an earth science class? What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom?

To answer these questions, I implemented a series of PBL scenarios with a class of eighth-grade students focusing on the SEM system while I attempted to use PBL as a vehicle to create a more equitable science classroom for all students.

Methodology. I collected each form of data in an attempt to answer both research questions of the action research study. A qualitative intrinsic case study was used to answer the research questions. The unit of analysis for this case study is me as the teacher-researcher and the 27 student participants. In an intrinsic case study, the researcher is interested in learning more about a specific situation and in understanding the case in great detail. The interest of the action research study was to gain insight into my perceptions as a new PBL tutor while conducting a series of PBL scenarios, while also attempting to disrupt stereotypical gender norms present in my classroom. I bounded this case study by the instructional and time-based boundaries of my classroom. The study took place during an eight-week unit of study where students explored the effects of the motions of the sun, earth, and moon; I also bounded this study by the eighth-grade students and the location of my classroom (Creswell, 2014).

Case study research uses as many sources of information as possible, as no one source of data has a complete advantage over all of the other sources of data (Yin, 1994). Creswell (2014) recommended multiple forms of data within a qualitative research study so that the researcher does not rely on a single source of data. Multiple types of data were acquired in the current action research study to gain insight into my perceptions of the classroom. In an attempt to answer the first research question, I maintained a journal describing my perceptions while conducting a series of PBL scenarios on the SEM system with a group of eighth-grade students in an earth/space science classroom to provide a detailed description of the classroom experiences. Periodically, a colleague evaluated my performance as a PBL tutor using a PBL evaluation tool (Garcia, James, Bischof, & Baroffio, 2017). Video blogs were created by all of the students in the classroom before the implementation of PBL and at the end of the unit of study. I used the PBL cycle (see Appendix A) for a series of PBLs on the SEM system. I used this methodology in an attempt to gain insight into my perceptions as a PBL tutor while disrupting stereotypical gender norms present in an eighth-grade earth science classroom.

Methods used in the action research study. Students were involved in a series of PBL scenarios focused on the SEM system. While exploring an ill-structured problem that reflects a PBL approach, students grappled with standards-based curriculum, including the rotation of the earth, the revolution of the earth around the sun, and the phases of the moon. To answer the first research question, I used data from student-created video blogs, pre- and post-assessments, and an analysis of the student responses to the transfer task on the post-assessment. To answer the second research question, I used data from two focus group interviews, student responses to the transfer task question on each of the three PBL post-assessments, three PBL tutor observations, and the reflective journal I maintained as the teacher-researcher.

Student-created video blogs. At the beginning of the SEM unit of study, students created an initial representation of their mental model of the SEM system. Students were asked to draw and explain their understanding of how the sun, earth, and moon move in space in relationship to phenomena observed on earth, such as the apparent motion of the stars, earth, and moon. I provided students with different spheres and other objects that they could use to aide their explanation. Each student created a video where they explained their mental representation of the SEM system. I collected this information to gain insight into the preconceptions of the students in my classroom as preconceptions impact science instruction and the learning process. Students were asked to create the same representation at the end of the unit of instruction and evaluate their initial representation. Students created a video blog of their final representation and evaluations of their initial diagram. I analyzed both student-created diagrams with a teacher-created rubric based on an evidence-based model of the SEM system (see Appendices C and D). I evaluated the growth of each student with a teacher-created rubric.

I selected six students following the initial pre-assessment to capture a variety of levels of student understanding. Three of the students are male students, and three of the students are female students. I analyzed the student video recordings as I transcribed both the video from the initial representation created by the students and the final representation created by the students. Following transcription of the student-created video blogs, I analyzed the data using an a priori coding scheme developed from the teacher-created rubric. I used these codes and patterns to answer the first research question.

Analysis of student pre- and post- assessment representations. Artifacts are written or visual data sources that may contribute to the understanding of what is happening in the classroom (Mills, 2018). Throughout the PBL scenarios, students created representations of their mental understandings of the SEM system. I analyzed artifacts of student learning from all 27 student-participants. The representations of the SEM system created by the students before and after the PBL experience were evaluated by a teacher-created rubric to determine their alignment with an evidence-based scientific model. I used the same rubric for the final post-assessment video created by each student. Each PBL scenario corresponds with a section of the rubric: For example, the first PBL on day and night corresponds with the day/night component of the teacher-created rubric. I used the same rubric to evaluate pre-assessments and post-assessments for each PBL scenario and the final student-created video (see Appendix D). I analyzed the representations in an attempt to determine if any changes have occurred in the mental representations of the student-participants and to identify lingering misconceptions from the pre-assessment to the post-assessment. When analyzing trends in growth in student understanding, data were coded using a priori codes developed from the teacher-created rubric. The evaluations of these representations were used to gain insight into my experiences implementing PBL in my classroom in an attempt to answer the first research question.

Analysis of student post assessment transfer task. Following the completion of each PBL, students completed a post-assessment that contained a transfer task question.

The transfer task asked each student to solve a complex problem similar in nature to the original PBL but with slight variations. The student responses to each transfer task were analyzed through a priori coding based on a teacher-created rubric (see Appendix E) in an attempt to answer the first research question.

Reflective journal. I maintained a journal throughout the action research study. Teachers continuously monitor the effects of their teaching practice and adjust accordingly and are active participants in the classroom environment. However, it is difficult to adequately reflect on experiences unless time is given to record our observations systematically. Therefore, a daily journal was used to capture my daily observations in a systematic way (Mills, 2018). The journal template for this action research study included prompts to attempt to isolate my perception of gender norms that may be present in the classroom environment (see Appendix F). Following the collection of data, the journal entries were coded using a thematic coding scheme (Yin, 1994) and analyzed for trends and patterns in an attempt to answer the second research question.

PBL tutor observations. During the action research study, two colleagues evaluated my performance as a PBL tutor using a teacher-created PBL rubric modified from Garcia et al. (2017) PBL evaluation tool (see Appendix G). The PBL tutor evaluation rubric was used to evaluate my performance as a PBL tutor. The rubric also asked the evaluator to gauge the participation of the cisgender male and female students in the study in an attempt to identify participation patterns and gender norms that may have been present in the classroom environment. Relevant observations, trends, strengths, and weaknesses were discussed to provide greater insight into the disruption of stereotypical gender norms within the classroom in an attempt to answer the second research question.

Focus group interviews. I conducted two focus group interviews during this action research study. Before the implementation of the PBL scenarios and following the completion of the PBL scenarios, six female students from the class under study participated in focus group interviews. A focus group interview is an interview that consists of several individuals who may be able to contribute to a deeper understanding of the research questions. I used a semi-structured interview schedule, and each participant was encouraged to respond (Mills, 2018). I conducted two focus group interviews to gain insight into the opinions of the female students regarding stereotypical gender norms that may be present in the science classroom and the process of learning through PBL. The focus group interviews took place before the PBL intervention (see Appendix H) and at the end of the series of PBL interventions (see Appendix I). I recorded and transcribed both of the focus group interviews. Student responses from focus group interviews were coded as they emerged, inductively following my analysis of the interviews, and I used these codes in an attempt to answer the second research question.

The focus group interviews were conducted to provide insight into both research questions. Questions in the focus group were used to gain insight into the perception of the students in the action research study for the use of PBL in the classroom to provide greater insight into my own experiences leading the PBL as a new PBL tutor. Other questions were asked to gain insight into gender issues that may influence the learning environment. In the school environment, many factors may influence girls' participation and achievement in science, including the curricula, learning materials, teaching strategies, and student interactions with the teachers (UNESCO, 2017). I used these factors in the development of the focus group questions.

Coding of qualitative data. Throughout the research process, qualitative data were coded and analyzed. Data were organized and sorted depending on the source of the data. I viewed all of the data and reflected on its overall meaning to gain a holistic understanding of the acquired data. Then, data were organized based on themes that emerged from the review of the data. Rossman and Rallis (2012, as cited in Creswell, 2014) defined coding as a process where one organizes data into chunks and describes the chunk using a word to represent a category. Codes are a phrase or word that captures the essence of a portion of qualitative data. I coded the data for patterns; patterns are repetitive occurrences that occur more than twice throughout the data. The data were coded in descriptive terminology to cluster similar occurrences together in found patterns. Following data collection, coding took place over several cycles to provide a deeper reflection on the emerging patterns. The entire dataset was transcribed and coded in an attempt to consider the smaller details of the daily life within the classroom as any section of the data could provide insights into the research questions using a priori codes to analyze student video blogs, pre-assessments, and post-assessments; emergent codes were used to analyze the research-journal, focus group interviews, and PBL tutor evaluations. I determined a priori codes before the analysis of student pre- and post-assessment as I created these codes based on the teacher-created rubric.

Emergent descriptive codes were used to analyze the focus group interviews, journal, and PBL tutor evaluation as the patterns and categories emerged through careful reflection. During the first round of descriptive coding, I coded data from the focus group interviews, reflective journal, and PBL tutor evaluation by finding the basic topic of a passage of qualitative data (Saldaña, 2016). After completing the first round of coding, I engaged in the second round of coding in an attempt to pull the entire dataset together to identify themes and explanations within the data using pattern codes. Pattern codes group summaries into a smaller set of themes or constructs. I used these methods in an attempt to describe to the reader my experiences as the teacher-researcher.

Tesch (1990, as cited in Creswell, 2014) discussed eight steps for coding data. I used the following steps to code the qualitative data using Tesch's guidelines thematically:

1. Organize data depending on the sources of information to get a sense of the whole.
2. Pick one document and go through it—ask yourself about the underlying meaning of the document.
3. Repeat this for several participants and make a list of topics; cluster these topics together of all topics.
4. Abbreviate the topics as codes and write the codes next to the appropriate segments in the data; see if new ideas or categories emerge.
5. Determine descriptive wording for topics and make them categories; attempt to combine similar categories to reduce the number of topics.
6. Abbreviate these categories and alphabetize these codes.
7. Assemble the data into each category and perform a primary analysis.

Following the coding and analyzing of the data, I reflected on my perceptions of PBL, gender norms, and conceptual change trends that emerged from the acquired data. Please see Appendix J for a description of the codes used in this study.

Validity and action research. Action research is subject to all threats of internal validity (Fraenkel et al., 2015)—I addressed these threats during the design of the study and throughout the action research process. Validity is "the appropriateness, correctness, meaningfulness, and usefulness of the specific inferences researchers make based on the data they collect" (p. 149). External validity is not a concern as the results of the study are not generalizable to a larger population.

I informed the students and parents of the students involved in the action research study before the start of the study. I provided parents with a waiver that allowed the participation of their child in the study (see Appendix K). However, this may have created a threat to the internal validity of the study, as the students were aware of their involvement in the study. As the teacher-researcher, I was completely aware and involved in the study, putting the study at risk for collector bias (Fraenkel et al., 2015). I attempted to report data and make inferences with as little bias as possible to reduce collector bias, taking care not to overlook any applicable student data. Fraenkel, Wallen, and Hyun (2015) argued that "implementation and attitudinal effects are also a strong possibility, as either implementers or data collectors can, unwittingly, distort the results of a study" (p. 593). Therefore, I did not alter any student data from the pretest and posttest and make inferences from the data objectively.

Developing Phase

The following phase of action research was the developing phase. Following the interpretation of the qualitative data, I determined a plan to modify future instruction based on the acquired data. An action plan was created based on the results from the analysis of the data acquired in this study. The action plan consists of two-steps and will be implemented in the following school year as the action research process continues. The action plan is described in Chapter 5: Action Plan and Implications for Future Practice.

Reflecting Phase

The final phase of the action research process is reflection; however, action research is a cyclical process and reflection occurred throughout the action research process. Action research can be beneficial to a teacher as it serves "as a rich source of ideas about how to modify and perhaps enrich one's own strategies and techniques" (Fraenkel et al., 2015, p. 594). Reflection by sharing the results "helps bridge the divide between research and application" (Mertler, 2014, p. 245). Other teachers and professionals may be interested in the outcomes of the action research process—the results could impact the educational practice in the classrooms of others (Dana & Yendol-Hoppey, 2014; Mertler, 2014).

Teachers should engage in the reflective practice in two main ways: throughout the research process and at the end of the action research cycle. Reflection happened every day throughout the action research process as I described my experiences within the reflective journal. Following the end of each PBL, I assessed student performance on the post-assessment through a rapid initial analysis. I recorded my feedback to each student and described the progress of each student. I used my reflection to shape each subsequent PBL experience and modified the PBLs based on what I have learned from the previous implementation of PBL. Mertler (2014) claimed that "professional reflection is a key component of the action research process and should be integrated thoroughly throughout each of the steps along the way" (p. 257). Reflection throughout the action research process can help guide instructional decisions.

As a teacher, I regularly engage in reflection while instructing; during action research, this process occurred in a more systematic process. At the culmination of the action research process, I analyzed the data and interpreted the results in an attempt to determine the impact of the action research. The action research process involves the development of an action plan as I hope to introduce the action plan to my school and district community. As a science teacher, I have an interest in developing an article or presentation for the National Science Teacher Association. Through the communication of action research, a teacher can inspire small and large-scale changes across the educational community (Dana & Yendol-Hoppey, 2014).

Professional reflection is an essential component of action research because the reflection process allows the teacher/researcher to make evidence-based instructional decisions during the action research cycle, leads to the development of an action plan, and ultimately changes the ways students experience school (Dana & Yendol-Hoppey, 2014; Mertler, 2014). Action research can be beneficial to a teacher, as it serves "as a rich source of ideas about how to modify and perhaps enrich one's own strategies and techniques" (Fraenkel et al., 2015, p. 594). Reflection by sharing the results "helps bridge the divide between research and application" (Mertler, 2014, p. 245). Other teachers and professionals are likely to be interested in the outcomes of the action research process—the results could impact the educational practice in the classrooms of others (Dana & Yendol-Hoppey, 2014; Mertler, 2014).

Summary and Conclusion

The current problem of practice involved the difficulty that the teacher-researcher has experienced while teaching the SEM system to eighth-grade students in a rural middle school in upstate South Carolina while creating a more equitable classroom for all students. I have attempted to answer the current research questions using Mertler's (2014) four-step action research cycle: planning, acting, developing, and reflecting. During the planning stage, I identified and limited the topic, gathered information, reviewed literature, and developed a research plan. During the acting stage, I collected and analyzed data. During the developing stage, I used the collected data to develop an action plan. During the reflection stage, I communicated the results and reflected on the action research process. Reflection occurred throughout the action research study in a systematic format; consistent reflection guided educational decisions throughout the unit of study. The current study met the tenets of action research as I attempted to provide a holistic description of my perceptions while implementing PBL in an attempt to address a local problem of practice; the reader may interpret the findings of this study to determine if the data is transferable to a separate situation or context.

Chapter 4:

Findings and Discussion

In this chapter, I explore the findings of the two research questions. I begin with the findings of the first research question: How does PBL impact the conceptual understanding of students in an earth science class? Then, I explore the findings of the second question: What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? To answer both questions, this action research study used a qualitative intrinsic case study design, as I described my role as a PBL tutor teaching within an eighth-grade science classroom and described my perspective of the PBL process using a variety of data sources (Creswell, 2014). Qualitative data were collected and analyzed using a coding scheme using a priori and emergent codes (Miles, Huberman, & Saldaña, 2014). To answer both questions, I describe my findings through an analysis of qualitative data and the discovery of emergent themes. I then discuss the inferences I have made from the findings for both questions. The chapter concludes with a summary of the key findings, a discussion of both research questions, and an introduction of the action plan that will be discussed in more detail in Chapter 5: Action Plan.

Findings: Research Question 1

The first question asked: How does PBL impact the conceptual understanding of students in an earth science class? I have included a discussion of the findings for the PBL process to provide insight into my experiences as a new PBL tutor. The three sources of data include student-created video blogs, student artifacts on a pre-assessment and post-assessment for each PBL, and student answers on a transfer task following the completion of each PBL. The three data sources were used to triangulate patterns found across multiple data sources and provide insight into my perceptions of the PBL process. In addition, excerpts from my reflective journal and focus group interviews have been included for depth in the findings for each research question as my reflection through each of the three PBL scenarios helped inform changes to instruction and create a more equitable classroom for all students.

The first data source is a summary of evidence of six student-created video blogs from the beginning and the end of the action research study. The video blogs demonstrate student understanding before the action research study and after the action research study. The video blogs capture the holistic understanding of the students from before the PBL process and their growth in understanding following the completion of the PBL process. The second data source is an analysis of the pre-assessments and post-assessments for each of the three PBLs. Students completed a pre-assessment before each PBL and a post-assessment at the end of each PBL. The pre-assessment and post-assessment were analyzed with a teacher-created rubric (see Appendix C). The pre-assessments provided insight to me as the teacher-researcher in the initial understanding of the student-participants and were used to modify instruction. The post-assessments gave me insight into the learning and conceptual growth of students from their participation in each of the three PBL learning experiences. Each pre-assessment and post-assessment cycle were used to inform instructional decisions and help me improve as a new PBL tutor. The third data source is an analysis of student-responses to a transfer task on the post-assessment for each of the three PBL learning experiences. The transfer task is a similar, but slightly different, problem comparable to the original PBL scenario. This task called for students to apply what they have learned through the PBL process to a different and challenging new problem, which provided me insight into the depth of student knowledge and their ability to transfer the content of the PBL problem to a different scenario.

Video Blogs

I began the PBL experience by showing the students a video of a time-lapse at Joshua Tree National Park. I asked the students to create a representation of what is happening in space to cause these objects to appear to move across the sky on earth. Students created a video recording explaining how their representation and how the motions of the earth, moon, and sun create phenomenon observed on earth. All of the initial video blogs were rapidly analyzed before instruction. The video blogs gave me insight into the prior knowledge of my students and were used to inform instructional decisions in the following class periods. I purposefully selected six students to demonstrate a variety of student preconceptions and development of ideas throughout the PBL process; three of the students are cisgender female, and three of the students are cisgender male.

Table 4.1

Student Video-Blog Responses to Joshua Tree Prompt

Student	Gender	Student Response	Assessment
Adrienne	Cisgender Female	In the Joshua tree view, you can see that as the sun rises, the moon goes away. In the space view, you can see that the earth moves around the sun and the moon moves around the earth. So by my understanding of this, in the Joshua tree view, the moon and stars go down as the sun rises, and sometimes you can see them together, but not always.	Developing
Matthew	Cisgender Male	On the Joshua tree, it looks like the stars, sun and moon are moving and the earth stays still. The space view you see what really happens, the planets move around the sun and stars and the moon moves around earth.	Developing
Tess	Cisgender Female	The earth is spinning around the sun as the earth itself is spinning the moon is the sun shadow on it, and the stars are just burning gas. Earth is rotating as well as it is rotating around the sun.	Developing
Bobby	Cisgender Male	The moon revolves around the earth while we and the earth moves around the sun. The reason the stars are moving is because the earth rotates.	Developing
Sean	Cisgender Male	Earth rotates around the sun while spinning at roughly 1,000 mph on its axis. The moon revolves around the earth and appears to move across the sky at night as it reflects the sun's light. The sun and stars also appear to move as earth rotates and spins. Sun rises in the east and sets in the west and on time-lapse, appears to move across the sky. The moon appears to move as it rotates around the earth.	Developing
Cindy	Cisgender Female	It shows how the moon and sun could both be seen at once. Since the moon is circling the earth and the earth is going around the sun, they can overlap in a new moon. The diagram shows how you can see the sun and moon at once in the sky. The earth is rotating, and it's going around the sun, and the moon is also whenever there is a new moon in the moon's cycle we can see them both at once	Developing

I assessed the video recordings and representations using a teacher-created rubric. I categorized all six initial student-responses as the a priori code "rotation developing understanding.” Zero student-representations were categorized as a priori codes “rotation approaches understanding” or “rotation meets understanding” in the initial video blog. Please see the codebook (Appendix J) for a description of each of these codes. Pseudonyms have been given to each student to protect his or her identity. See Table 4.1 for the description of student video-blog responses.

Table 4.2

Student Video-Blog Responses for Three Astronomical Concepts

Student	**Gender**	**Star, Sun, and Moon Rise**	**Seasons**	**Moon Phases**
Adrienne	Cisgender Female	Developing Understanding	Approaches Understanding	Approaches Understanding
Tess	Cisgender Female	Meets Understanding	Meets Understanding	Approaches Understanding
Cindy	Cisgender Female	Meets Understanding	Meets Understanding	Meets Understanding
Matthew	Cisgender Male	Approaches Understanding	Meets Understanding	Meets Understanding
Bobby	Cisgender Male	Meets Understanding	Approaches Understanding	Meets Understanding
Sean	Cisgender Male	Meets Understanding	Meets Understanding	Meets Understanding

Following the completion of three PBL scenarios on the day and night cycle, seasonal change, and moon phases, students created a final video blog to showcase what they have learned. I assessed the final video-blogs with a teacher-created rubric (Appendix D). For this video blog, the prompt asked students to create a representation of the causes of the appearance of the rising of the sun, moon and stars, seasonal variation, and moon phases. Table 4.2 includes a summary of student responses categorized using a priori codes. See the codebook for a description of codes (Appendix J).

Adrienne. Adrienne stated in her initial video blog,

> In the Joshua tree view, you can see that as the sun rises, the moon goes away. In the space view, you can see that the earth moves around the sun and the moon moves around the earth. So by my understanding of this, in the Joshua tree view, the moon and stars go down as the sun rises, and sometimes you can see them together, but not always.

In the pre-assessment for day/night and earth rotation, Adrienne included in her representation a drawing of the moon blocking the light from the sun during the nighttime. I described in my journal,

> Adrienne had shown in her original drawing that the moon blocks the light from the sun during the nighttime. On her team drawing, she had the moon in her drawing. I talked to her team about this, and asked if we really needed a moon shown for day and night. The other two young women in her team responded "No!" But Adrienne … said, "wait … Yes, we do … Right?" She seemed a bit unsure, so I talked to her quietly about it and set up the demo. In her final video, she provides a correct response to the reason for seasons and moon phases, but she still says, "Why we have sunrise and sunset because the moon revolving around us blocking us from the sun when the moon goes away we have day."

While her responses for seasonal change and moon phases were correct, they were lacking detail but did not contain evidence of misconceptions as her response to the day and night PBL post-assessment. Following the three PBL instructions, Adrienne still grappled with misconceptions about the moon blocking the light of the sun at night.

Tess. Tess described in her pre-assessment, "The earth is spinning around the sun as the earth itself is spinning the moon is the sun shadow on it and the stars are just burning gas. Earth is rotating as well as it is rotating around the sun." In her post-assessment, she describes moon phases: "Moon phases are caused by our rotation and the moon's rotation. We see different phases also depending on where we are on the earth and how we are seeing the moon on its rotation." While this is correct, her response was lacking detail, and she did not create a visual representation of the phenomenon. Tess had expressed several times that she was still struggling to understand moon phases, even after the moon phase PBL; this is evident in both the reflective research journal and the second focus group interview. For example, she stated in the second focus group interview, "Um, yeah I learned a lot and mine have been really close recently except for the moon one. I really still don't know what's going on with the moon." However, I categorized her moon phase post-assessment for the third PBL as "moon phases meets understanding," which is the most proficient category of understanding on the teacher-created rubric. She expressed during the focus group, "I have like, a photographic memory. I just memorized the diagram and told you everything I remembered!" During the second focus group interview, Tess speaks of the difficulty she experienced working with the mix-gender group including her and two male students:

> Tess: … mm… this one… I hated this one. Normally I like them, but working with two boys, especially the boys I was working with, was not the easiest thing, and they are controlling like me. And, literally the only thing they had me do was color. So, I mean, they are really smart, and they think a lot of themselves, but I

just think, just working with two boys, but I mean … what's the word, they were kind of um …

Cindy: Dominate?

Tess: Yeah, and me dominate too, is, really hard … so. But I mean you can get through it. We got through it. It's possible. It's just … I don't like it that much.

In my research journal, during the class before the final post-assessment, I described,

> Two of the female students complained about not understanding the material. I worked with them for a bit, and they both received excellent grades on the post-test. However, I believe that they memorized the appropriate diagram and did not fully understand the process of moon phases.

Tess was one of these students. Later, when the student-participants were creating their final video blogs, I described,

> The same student who said she did not understand moon phases before the post-test on moon came to me and said she still didn't get it. I asked her how she got a 100 on the test. She said, "I just memorized it. I have a photographic memory. I didn't understand it at all." So, we took some time to discuss the diagram again. She was like … "MY DIAGRAM NEEDS A SUN!" She tried to put the sun in a strange place … and I told her that she can't put the sun just anywhere. She said, "then where do I put it?" And I said think about what would make sense for day/night on the moon. That made it seem like it clicked for her a bit more, but I am still concerned the moon PBL was not as beneficial to her as the other two PBL experiences.

Tess described her success with the other two PBL scenarios on earth rotation and seasonal variation and her difficulty with the moon phase PBL in the second focus group interview: "I really understood really well the sun, and the earth, and seasons and what not, but, to this day I still do not have a clue about the moon, so yeah I'm not kidding!"

Cindy. Cindy described in her pre-assessment,

> The diagram shows how the moon and sun could both be seen at once. Since the moon is circling the earth and the earth is going around the sun, while rotating, they can overlap in a new moon. So the diagram shows how you can see the sun and moon at once in the sky. From space because the earth is rotating, and it's going around the sun and the moon is also whenever there is a new moon in the moon's cycle we can see them both at once

While her initial representation was categorized with a priori code of "developing understanding," Cindy may have come into this experience with stronger background knowledge than expressed in her video. For example, during the pre-assessment, she argued with her neighbor about what causes the rising and setting of the moon, stars, and sun. She argued it was the spin of the earth, and he argued it was the movement of the moon around earth. In my journal, I reflected: "I overheard one discussion where Cindy was explaining to Matthew that the stars appear to move because the earth is rotating. He disagreed and said that everything in space is moving." In her final video reflections, she provided an extremely thorough explanation of all of the astronomical concepts under study during the PBLs.

Matthew. Matthew described in his video blog, "On the Joshua tree, it looks like the stars, sun and moon are moving and the earth stays still. The space view you see what really happens the planets move around the sun and stars and the moon moves around earth." In his post-assessment, he described,

> The reason we have sunrise and sunset is because the earth orbits the sun while it is spinning. And while we are on earth it gives us the appearance the sun is rising and setting and the same thing is going for the moon and the moon orbits the earth and the earth is spinning while the moon orbits the earth and it gives us the appearance that the moon is rising and setting.

In both the pre-assessment and the post-assessment, he does not clarify which motion causes sunrise and sunset.

Bobby. Bobby described in his pre-assessment: "The moon revolves around the earth while we and the earth moves around the sun. The reason the stars are moving is because the earth rotates." While he related the rotation of the earth to the apparent spinning of the stars, he did not relate the rotation of the earth to the rising and setting of the sun and moon. In his final video blog, he used a lamp to represent the sun and a sphere to represent the earth. He described, "The reason we have it is because of the rotation of the earth." He showed the earth spinning. He described where we are on the sphere and has the sun over-head and describes "now its high in the sky and we will soon go into darkness as the sun appears to move across the sky." However, for the moon, he showed the moon revolving around the earth to show where the moon is low in the sky and high in the sky. His video blog was unclear about how earth rotation causes the rising and setting of the moon. He provided a thorough description and model of why the earth experiences seasonal changes and moon phases.

Sean. Sean described in his pre-assessment,

> Earth rotates around the sun while spinning at roughly 1,000 mph on its axis. The moon revolves around the earth and appears to move across the sky at night as it reflects the sun's light. The sun and stars also appear to move as earth rotates and

spins. Sun rises in the east and sets in the west and on time-lapse, appears to move across the sky. The moon appears to move as it rotates around the earth.

His pre-assessment showed the moon moving across the sky due to its revolution around the earth. In his post-assessment, he described "we have sunrise and moonrise and sunset and moonset due to earth's rotation. As we spin, it appears that the sun and the moon fly across the sky but it's just us spinning," showing evidence of conceptual growth for earth's rotation. His post-assessment was also categorized as "meets understanding" for phases of the moon and seasons as he provided an in-depth explanation of all of the astronomical concepts covered during the three PBL scenarios.

PBL 1—Day and Night

For the first PBL on day and night, I used three data sources in an attempt to provide insight into the conceptual understanding of the students engaged in this PBL. The three data sources include student responses to the pre-assessment, post-assessment, and transfer task. For the first PBL on day and night, I coded the majority of the representations created by the class as "approaches understanding" for the pre-assessment. I assessed the models with a teacher-created rubric (Appendix D). Following instruction, students completed a post-assessment and I also assessed these student-representations using a teacher-created rubric (Appendix D) and I coded all of the final diagrams as "meets understanding," showing significant growth across the class from the pre-assessment from the post-assessment. However, overall performance on the transfer task section of the post-assessment was lower than the performance on the model section of the post-assessment. This PBL uncovered that students entered the learning experience with a variety of misconceptions. Many of the students demonstrate evidence of conceptual growth following the PBL experience, however about a third of the students showed difficulty transferring the information to a slightly different scenario in the transfer task.

I created the first PBL experience based on the McConnell et al. (2017) PBL framework. Writing this PBL allowed me to grapple with the complexities of becoming a more proficient PBL tutor and better understand the PBL process. For this PBL, I created groups of students and organized the grouping based on gender. I created teams of all females and teams of all males. I used the McConnell et al. (2017) framework to create the instructional design of the PBL process. The instructional design was similar for each of the three PBLs:

1. Student completes a pre-assessment on the PBL problem.
2. Assign teams and introduce the PBL story.
3. Have students complete a discussion activity.
4. Cycle through research within the group and modeling activities.
5. Students create their model as their final PBL solution.
6. Complete a classroom Socratic seminar to discuss the findings of each team.
7. Students complete a post-assessment on the PBL problem.
8. Students are given an opportunity to correct their post-assessments following a discussion of possible post-assessment solutions.

The pre-assessment and post-assessment data and the student-responses on the transfer task provided insight into my perceptions as the PBL tutor and were used to modify instruction in future PBL learning experiences.

Pre-assessment data. The students entered this learning experience with a variety of preconceptions and misconceptions. I asked the students to draw a representation of their initial understandings of why the earth experiences day and night. I evaluated the representations with a teacher-created rubric (Appendix D). I categorized three student representations as the a priori code "rotation developing understanding," 24 student representations as "rotation approaches understanding," and 0 student representations as "rotation meets understanding." I completed a rapid analysis of this data immediately following the pre-assessment and used this information to help guide instruction. For example, these data showed that the majority of the class showed evidence of a developing understanding of earth rotation, and a few students showed evidence of having misconceptions about earth rotation and day and night. The rapid initial analysis allowed me to use this information to work with individual students in more detail and provide more complex instruction and questions to students who had a more developed understanding of the concept. I completed a more detailed analysis of the data after instruction to help me gain insights from the PBL experience. Please see the codebook (Appendix J) for a description of codes.

Post-assessment data. Following the PBL experience and Socratic seminar, students completed a post-assessment on day/night and the rising and setting of the sun. These data were used to provide a greater understanding of my effectiveness as a PBL tutor and insights into the conceptual growth of the student-participants. Student-participants were asked to draw a representation of why the earth experiences day and night. I used a rubric to assess student representations (Appendix D). For the final model, all 27 students scored in the "rotation meets understanding" category.

Transfer task. While all 27 students created a representation of day/night and earth rotation that aligned with an evidence-based scientific representation, several students did not correctly answer the transfer task about sunrise and sunset and how the sun moves across the sky throughout the day. For the rotation transfer task, 19 students related sunrise and sunset to the rotation of the earth thus falling in the category of "meets understanding." Five students related sunrise and sunset to earth rotation but may not have represented the rotation of earth correctly or differentiated earth's rotation from revolution.

Table 4.3

A Priori Code Data for Day/Night Pre-Assessment and Post-Assessment

	Pre-Assessment		**Post-Assessment**	
A Priori Code	Frequency	Percent	Frequency	Percent
Meets Understanding	0	0	27	100
Approaches Understanding	23	85.185	0	0
Developing Understanding	4	14.814	0	0
Total	27	100	27	100

Three students described sunrise and sunset caused by the motions of the earth around the sun, instead of the rotation of the earth on its axis. See Table 4.4. For example, one student wrote we have "sunrise and sunset because the Earth spins towards the east. That's why we see the sun first and our clocks are faster." However, he drew the motion of earth going around the sun to represent day/night. He described later in the test, "The sun doesn't rise or set, it's just the earth spinning on the axis." There were several other examples of students who used correct terminology or described the correct process but did not create an accurate diagram to represent why the sun would rise and set to correlate with their written explanation.

Table 4.4

A Priori Code Data for Day/Night Transfer Task

	Transfer Task	
A Priori Code	Frequency	Percent
Meets Understanding Transfer Task	19	70.370
Approaches Understanding Transfer Task	5	18.519
Developing Understanding Transfer Task	3	11.111
Total	27	100

Reflection. The pre-assessment data showed how many of the students in the classroom had a developed understanding of day and night as caused by the rotation of the earth, but I identified zero of the students as having a pre-assessment response as “meets understanding” as evaluated with the teacher-created rubric. Several of the students entered the experience with misconceptions about day/night and the rotation of the earth. Therefore, I provided a PBL learning experience to meet the needs of students who may have misconceptions, as well as challenge students who show evidence of an evidence-based understanding of the sun and earth system.

Throughout the PBL process, I consistently reflected on my growth as a PBL tutor. For example, I discussed student voice in the classroom in one of my journal entries:

> Even while working with groups, one person would volunteer to answer. When working with each group, it would help me if I asked for everyone to contribute in answering questions during the earth/sun demonstration.

I also noticed which teams and individuals received the greatest amount of instruction. On the second day of instruction, I described:

> I did seem to be working mostly with the boys' groups. They kept raising their hand and asking for feedback. The young women rarely asked for help and I had to keep trying to get over to help them, but the boys seemed eager to ask for help, while the girls were diligently working without my help.

I also described the difficulty in providing support as a PBL tutor during the first PBL learning experience:

> Let groups explore a bit more on their own. I may be over-guiding as a PBL tutor when it comes to developing topics for research within the PBL. It is difficult to guide the students without providing too much support for the students. We are still early in learning how to complete PBLs, so I think, or really hope, that students will learn more about how to guide themselves.

Throughout the PBL process, I intentionally reflected in an attempt to improve as a PBL tutor and also to create a more equitable classroom for all students. I struggled with making sure all group members participated in both in small-group and whole-group discussions. I also experienced difficulty in knowing how to balance the amount of support to group members in developing a solution to the PBL problem and helping focus their research.

In addition, I analyzed the post-assessment final models in an attempt to gain insight into the effectiveness of the PBL process and to make instructional changes for the next two PBL scenarios. After the final group discussion and post-assessment, I described in my journal:

> It is amazing to me how misconceptions can linger despite focused and intentional science instruction. I think that this PBL approach has changed the way I think when it comes to instruction. Most of the kids did "get" this by the test, but when they were asked to complete the transfer task and application questions, many struggled to apply how the earth spins to the east, where sunrise would be, and how places can experience daytime and nighttime at the same time or different times. These questions made all students really think about what they know and apply it to a different scenario, which was pretty cool to see.

Essentially, I described how students thoroughly explained the concept and material included in the PBL in their final model on the post-assessment, but some students still had misconceptions; also, some students appeared to experience difficulty when transferring the information to a new and different scenario during the transfer task. Therefore, the pre-assessment, post-assessment, and transfer task provided insight into my perceptions of the PBL process.

PBL 2—Seasons

For the second PBL experience on seasons, I modified an existing PBL written by McConnell et al. (2017) to align with the 2014 South Carolina Science Standards more closely. From reflecting on the first PBL, I learned the importance of not over-guiding the thinking of both individuals and groups. I also realized students seemed to experience difficulty transferring information to a new scenario, so I attempted to increase questioning strategies during the PBL to help students really think about the context of the problem and the content they were learning. For this PBL, I allowed students to choose their group members. Students worked in collaborative teams of three to four students. The instructional design followed the same process as the other two PBL scenarios: Students completed a pre-assessment on seasons, analyzed and discussed the PBL story, completed researching and modeling activities, developed their solution, participated in a Socratic seminar on the PBL topic, and completed a post-assessment on the PBL problem.

Three sources of data were used to provide insight into the conceptual understanding of the student-participants before the PBL experience and after the PBL experience. The three sources of data include student responses to the pre-assessment, post-assessment, and transfer task. For the second PBL on seasons, the majority of the representations created by the class were coded as "developing understanding" for the pre-assessment. The pre-assessment revealed that the majority of the students in the class showed evidence of misconceptions or lack of conceptions about why the earth experiences seasonal change. I assessed the models with a teacher-created rubric (Appendix D). Following instruction, students completed a post-assessment. I assessed the models created by the students with a teacher-created rubric (Appendix D), and the majority of the representations were coded as "meets understanding," showing significant growth across the class from the pre-assessment from the post-assessment. Student performance on the transfer task was the higher for this PBL than the other two PBLs on day and night and moon phases.

Pre-assessment data. In an attempt to understand the preconceptions and misconceptions of the student-participants, I asked the students to draw their initial understandings of why the earth experiences seasonal change over the year. I then evaluated student-created representation with a teacher-created rubric (see Appendix D).

Students showed evidence of a variety of preconceptions that differ slightly to substantially from the accepted scientific evidence-based model of seasonal change. I completed a rapid analysis of this data immediately following the pre-assessment and used this information to help guide instruction. The rapid analysis revealed the prevalence of misconceptions across the student-participants in this class. For example, nine students describe seasons as caused by the distance of the earth from the sun. I described in my reflective journal: “After analyzing the pre-assessment data, I found that the majority of the class does not understand seasonal change on earth.” I used this information to inform instructional decisions throughout the PBL scenario. I completed a more detailed analysis of the data after instruction in an attempt to gain insights from the PBL experience (see Table 4.5).

For the pre-assessment on seasons, I categorized 19 of the student-representations “developing understanding seasons” using the teacher-created rubric. Many of these students may have misconceptions or lack of conceptions about seasonal change. I categorized eight of the student-representations as “approaches understanding seasons.” The representations of these students were more closely aligned with a scientific evidence-based model of seasonal change but did not include enough explanatory details to be categorized as “meets understanding seasons.” Within the student representations categorized as “developing understanding,” evidence of a variety of misconceptions emerged. The majority (11) of students in the class with misconceptions described seasonal change caused by incorrect notions of the changing distance of the earth from the sun.

Post-assessment data. Following the PBL experience on seasons and the Socratic seminar, students completed a post-assessment on seasonal variation. All students improved in their final representation of an evidence-based model of seasons. Using the same rubric used to assess their pre-assessment (Appendix D), I classified the student representations into three a priori categories: seasons developing understanding, seasons approaches understanding, and seasons meets understanding. The representations of 26 students were classified as "seasons meets understanding." One student representation was categorized as "seasons approaches understanding." Zero student representations were classified as "seasons developing understanding." See Table 4.5 for comparison.

Table 4.5

A Priori Code Data for Seasons Pre-Assessment and Post-Assessment

	Pre-Assessment		**Post-Assessment**	
A Priori Code	Frequency	Percent	Frequency	Percent
Meets Understanding	0	0	26	96.296
Approaches Understanding	8	29.630	1	3.449
Developing Understanding	19	70.370	0	0
Total	27	100	27	100

Transfer task. The transfer task called for students to transfer their knowledge of seasonal change to a new problem. The problem asked students to make inferences about seasons in the southern hemisphere and asked questions about seasonal change at the Arctic Circle. I classified twenty-six student representations as "meets understanding," one as "approaches understanding," and zero representations as "developing understanding." See the Table 4.6.

Table 4.6

A Priori Code Data for Seasons Transfer Task

	Transfer Task	
A Priori Code	Frequency	Percent
Meets Understanding Transfer Task	26	96.296
Approaches Understanding Transfer Task	1	3.449
Developing Understanding Transfer Task	0	0
Total	27	100

Reflection. The initial pre-assessment revealed the confusion across the class regarding the cause of seasonal variation. I described in my journal,

> During the pre-test, I noticed most of the students believe the earth is closer to sun in summertime than it is in wintertime. There was some major upset during the pretest as students became frustrated with their own mental representation. For example, one female student drew the earth as closer to the sun in summer and further in winter, but realized it wasn't the distance that could explain why southern hemisphere has opposite seasons.

This PBL, in particular, seemed to be effective in showing the students in this rural southern classroom how different places have different seasons. I described, "Many of my students assume that all places have four seasons and that the seasons are the same everywhere."

However, I noticed some issues in the PBL process throughout this particular PBL. For example, I reflected,

> It may be beneficial to break up PBLs with different types of instruction. The readings for the PBL scenario were a bit long, and the kids were starting to lose focus. To break it up, daily instruction typical to the classroom can be incorporated into the PBL experience. It should ADAPT to the students you teach … PBL in a middle-level classroom is going to look different than a PBL in a college/medical situation.

It seemed like some of the students became increasingly disengaged throughout this PBL process. There were several journal entries where I described my frustrations and made changes as a PBL tutor. I observed how misconceptions made the PBL process more difficult as I balanced the challenge of either providing too little support or providing too much support in the inquiry process:

> It is really difficult for groups to identify research topics and develop a hypothesis if they have misconceptions. I think working in teams really helps with the "misconception" part of this … I saw a lot of team members explaining the concept to each other. The group teaching was pretty awesome to see. We also used a video clip to help fill in the gaps in knowledge—this seemed to help.

The organization of resources for each PBL also emerged as an issue in the PBL process. I described in my journal,

> I need to make my "resource folder" better. … I had a few printouts available, but I was having a hard time balancing hands-on activities, the resources I have picked out, and students' individual research. Because I see the kids every other

> day, it is difficult to intertwine the PBL research and laboratory experiences. I think that these PBLs may work better with just one lab experience …

I also noticed the emergence of gender, inequities, and stereotypical gender beliefs emerge in this PBL. I described the Socratic seminar experience in my journal:

> Several of the male students became frustrated when corrected by their peers. One male student seemed offended when a female student offered an explanation to his question. The male students spoke many more times than the females, but a few of the females made their voice heard during the discussion. Every student spoke at least once as this was the requirement of the discussion.

Following the rapid analysis of the PBL posttest, I reflected on this data and used it to offer remediation and to modify future instruction. I observed after assessing the post-assessments: "Most of the students did not relate tilt to amount of daytime and nighttime. … I may need to reiterate this next class." Because this was commonly not included on student-responses in the post-assessment, I remediated in the following class to address this detail.

PBL 3—Phases of the Moon

The third PBL was adapted from the McConnell et al. (2017) PBL on phases of the moon. I modified an existing PBL written by McConnell et al. based on what I have learned from implementing the previous PBL scenarios. For this PBL, I assigned each student to a team for their PBL; the teams were mixed-gender, and I attempted to separate students from their friends. Students worked in collaborative teams of three to four students. The instructional design followed the same process as the other two PBL scenarios: Students completed a pre-assessment on moon phases, analyzed and discussed the PBL story, completed researching and modeling activities, developed their solution, participate in a Socratic seminar on the PBL topic, and completed a post-assessment on the PBL problem. I completed a rapid analysis of this data immediately following the pre-assessment and used this information to help guide instruction. I completed a more detailed analysis of the data after instruction in an attempt to gain insight into the PBL experience. After completing the previous two PBLs and reflecting, I attempted to make the resources for the PBL research easier to access for the teams. I also attempted to address misconceptions early in the PBL process through modeling, as the misconceptions seemed to hinder the ability of the groups to find solutions to the PBL in the previous two PBL scenarios.

Three sources of data were used to provide insight into the conceptual understanding of the student-participants before the PBL experience and after the PBL experience. The three sources of data include student responses to the pre-assessment, post-assessment, and transfer task. For the third PBL on phases of the moon, I coded a little over half of the representations created by the class as "developing understanding" for the pre-assessment and a little less than half as "approaches understanding." The pre-assessment revealed that the majority of the students in the class show evidence of misconceptions or lack of conceptions about why the earth experiences phases of the moon. I assessed the models with a teacher-created rubric (Appendix D). Following instruction, students completed a post-assessment. I also assessed the final models created by the students with a teacher-created rubric (Appendix D), and I categorized the majority of the representations as "meets understanding," showing significant growth across the class from the pre-assessment from the post-assessment. However, there were more students whose representations were assessed in the lower categories of performance for this post-assessment than the other two post-assessments. Student performance on the transfer task was lowest for this PBL in comparison to the other two PBLs on day and night and seasons.

Pre-assessment. In an attempt to understand the preconceptions and misconceptions of the student-participants, I asked the students to draw their initial understandings of why we see the moon go through different phases. I evaluated student-created representations with a teacher-created rubric (Appendix D). I completed a rapid analysis of this data immediately following the pre-assessment and used this information to help guide instruction. I completed a more detailed analysis of the data after instruction to help me gain insights from the PBL experience. Fifteen student-representations were categorized as "moon phases developing understanding," 12 were classified as "moon phases approaches understanding," and 0 were categorized as "moon phases meets understanding." Please see the codebook (Appendix J) for a description of these a priori codes.

Student representations classified as "moon phases approaches understanding" described the moon revolving around the earth relative to the sun, causing moon phases, but were missing explanatory detail. Student representations classified as "moon phases developing understanding" either demonstrated a lack of conception or misconceptions. I identified a variety of misconceptions from the rapid analysis of the pre-assessment. Five students did not know what motions of the sun, earth, and moon cause moon phases. Four students confused the placement of the different moon phase positions. Other misconceptions included clouds blocking the moon and causing moon phases and the shadow of the earth on the moon causing moon phases.

Post-assessment. Following the completion of the phases of the moon PBL and Socratic seminar, students completed a post-assessment on moon phases and moonrise/moonset. I assessed student work using a teacher-created rubric that was also used to evaluate the pre-assessments (see Appendix D). Of the student-participants, I identified 23 representations as "meets understanding moon phase," two as "approaches understanding," and two as "developing understanding." See Table 4.7 for a comparison of student pre-assessment and post-assessment for the moon PBL.

Table 4.7

A Priori Code Data for Phases of the Moon Pre-Assessment and Post-Assessment

	Pre-assessment		**Post-assessment**	
A Priori Code	Frequency	Percent	Frequency	Percent
Meets Understanding	0	0	23	85.185
Approaches Understanding	12	44.444	2	7.401
Developing Understanding	15	55.555	2	7.401
Total	27	100	27	100

The student-representations classified as "moon phases approaches understanding" showed the correct understanding of why the earth experiences moon phases and moonrise/moonset, but the representations did not include explanatory details. Student representations classified as "moon phases developing understanding" still contained misconceptions or lack of conceptions. Detail varied across all student work: Some student-representations included a variety of explanatory detail, while other student-representations lacked explanatory detail. Performance on this post-assessment provided insight into my perceptions of the PBL process.

Transfer task. The transfer task called for students to apply their knowledge of the phases of the moon. Twelve student representations were classified as "meets understanding transfer task," 11 representations were classified as "approaches understanding transfer task," and four representations were classified as "developing understanding transfer task." See the Table 4.8 and Appendix J for a description of the a priori codes.

Table 4.8

A Priori Code Data for Phases of the Moon Transfer Task

	Transfer Task	
A Priori Code	Frequency	Percent
Meets Understanding Transfer Task	12	44.444
Approaches Understanding Transfer Task	11	40.741
Developing Understanding Transfer Task	4	14.815
Total	27	100

Reflection. The initial rapid analysis of the pre-assessment data demonstrated about half of the class had misconceptions about phases of the moon, such as the phases of the moon caused by the shadow of the earth on the moon, clouds causing changing moon phases, or incorrectly marking the position of the new and full moon. The other half of the class seemed to have a correct general idea, but their diagrams were lacking explanatory detail. I described in my reflective journal, "I knew specifically which students had misconceptions after viewing their pre-assessments, which was extremely helpful." This data helped inform the following days of instruction. During this PBL, I assigned mixed-gender groups. One student seemed unhappy with her group assignment. I wrote in my reflective journal,

> Tess was not happy about the two male students she was assigned to work with. She asked if I could help her team and make sure the work was divided up evenly—I agreed to help. She wanted to be able to do her part and was worried the two other boys wouldn't let her pull her share.

I described how my implementation of this PBL was more effective than the previous PBL experiences. I wrote in my journal, "I have made a lot of subtle changes between the PBLs including modifying the resources, to providing background knowledge, to organizing the brainstorming, to integrating labs into the PBL." However, while I have made improvements, there is room for growth. For example, I described, "also, I still need to work on my role as a tutor. I help students too easily, and need to let the kids 'suffer through' more and ask probing questions." In summary, I noticed a few groups struggle in equal collaborations, the changes that I have made through the series of PBLs have seemed to be helpful, and balancing the amount of support given to each team was still difficult even in the final PBL experience.

Discussion: Research Question 1

Three forms of data were used for triangulation for Research Question 1 including the final video blog pre-assessment and post-assessment, student-created representations for pre-assessment and post-assessment for each of the three PBL scenarios, and student responses to the transfer task question for three post-tests. These data sources indicate my implementation of PBL in an eighth-grade earth science classroom was somewhat successful in fostering conceptual change. The discussion for research question one is analyzed by a discussion of inferences from each of the three data sources and concludes with a discussion of the findings from the triangulation of all three data sources.

Video Blogs

I purposefully selected three female students and three male students who displayed a variety of growth during the PBL process to describe the varied-nature of student success. All of the students displayed varying levels of growth in each area from their initial video to their final video. One student still showed evidence of her initial misconceptions about day and night in her final video. Adrienne described in her final video that we have nighttime because of the moon blocking the light of the sun. This misconception was still evident even after inquiry-based instruction through PBL and direct interaction between the student and me regarding this concept. Because this misconception still revealed itself in her final video reflection, it speaks of the difficulty of addressing student preconceptions in an eighth-grade earth science classroom. Her other two responses for seasons and moon phases met the qualities of the a priori code "approaches understanding," as she described the correct process for moon phases and seasons; however, her description is lacking explanatory detail.

Tess provides a detailed response to the earth rotation and season's prompt that I identified as "meets understanding." However, her moon phase's response was categorized as "approaches understanding," as she did not include explanatory detail. She described her perceptions of the moon phase PBL and noted how she did not "like it that much." She was working with two young men whom she and Cindy describe as "dominate," and she speaks of how in the process of collaboration "literally the only thing they had me do was color," during the second focus group interview. Her video blog revealed her lack of understanding of moon phases as she created a detailed explanatory model of seasons and rotation of the earth, but her diagram of moon phases lacked explanatory detail. During the creation of this video, she approached me several times for assistance in creating her moon phase video blog and described how she just memorized what she needed to do for the post-assessment but didn't understand the moon phases. She found success in the first two PBLs on earth rotation and seasons; she was able to create a video blog discussion of these concepts easily and described her confidence in her knowledge of these topics in the second focus group interview. This indicates the implementation of PBL was successful for Tess during two scenarios but less effective for the third scenario on moon phases.

Matthew appeared to have lingering confusion about which motion of the earth and sun cause the rising and setting of the sun. For example, in his first video-blog, he discussed how "what really happens, the planets move around the sun," when describing the path of the sun across the sky. He did not clarify which motion causes the rising and setting of the sun in his final video blog as he described the "earth orbits the sun while it is spinning." He mentioned, "the moon orbits the earth, and the earth is spinning while the moon orbits the earth and it gives us the appearance that the moon is rising and setting." While he described correct motions, he did not relate the motion to the observed phenomenon of the apparent rising and setting of the moon and sun. Bobby described and represented the correct motion of earth's rotation causing sunrise and sunset, however, he showed the moon revolving around the earth to cause moonrise and moonset.

In general, students displayed growth from first video blog to the last video blog. Even the students who contained lingering misconceptions about a particular phenomenon were able to explain other concepts in detail. For example, Matthew did not correctly explain moonrise and moonset; however, he provided a thorough explanation of the rising and setting of the sun, day and night, phases of the moon, and seasonal change. While Tess expressed difficulty with understanding phases of the moon, she was confident in describing seasonal change and the apparent rising and setting of the sun and moon. Bobby did not clearly show the rotation of the earth causing sunrise and sunset, but he provided a thorough explanation of seasonal variation and moon phases. Both Cindy and Sean included a thorough explanation of all three astronomical occurrences with exceptional explanatory detail.

Pre-Assessment and Post-Assessments

Prior to each PBL, students created a representation of their conceptions of a scientific phenomenon. Following the PBL learning experience, each student received their original pre-assessment diagram and was asked to create a more detailed explanatory model for the scientific phenomenon under study. For each of the three PBLs, students displayed varying levels of growth from the pre-assessment to the post-assessment. I identified all of the student-representations as "meets understanding" for the post-assessment on Day/Night, but most of the students entered the learning experience with a developed understanding of this concept as identified by the pre-assessment. Student performance on the post-assessment for the Seasons PBL showed the greatest amount of growth in conceptual understanding by the student-participants as many of the students entered the learning experience with misconceptions; by the end of the PBL, I identified 26 of the 27 students as "meets understanding." The phases of the moon PBL seemed to show the least amount of growth than the other three PBLs; however, the I identified the majority of the class as "meets understanding" for their final representation.

Transfer Task

After students completed their final representation, they were asked to answer several questions in a transfer task question. In comparison to the student-created diagrams, the percentage of student-responses for the transfer task was lower in the "meets understanding" category and the percentage of student responses in "approaches understanding" and "developing understanding" categories are higher for each of the three PBLs. Therefore, while all students demonstrated growth in their mental representations of the sun, moon and earth system, some students did not successfully transfer this knowledge to a new problem scenario. For the three PBLs, more of the students were successful on the Seasons Transfer Task than the other two transfer task questions. The students were the least successful on the Phases of the Moon Transfer Task; this transfer task question was more challenging than other two transfer task questions, which could explain the lower performance on this particular question.

Discussion

Based on the growth from the initial video blog and the final video blog, the implementation of PBL by the teacher-researcher appears to be somewhat effective in developing conceptual understanding of astronomical concepts in this particular eighth-grade earth science classroom. However, a few of the students demonstrate the difficulty of conceptual change, as misconceptions still appear in their final videos. Also, a few of the students showed difficulty relating the exact motion of the sun, earth, and moon to the observed phenomenon on earth. For example, Matthew described sunrise and sunset because of the rotation of the earth and the revolution of the earth around the sun; however, only the rotation of the earth on its axis causes the sun to appear to rise and set. All of the final post-assessments show growth in understanding represented in the student-created diagrams. However, the third PBL on phases of the moon showed the least amount of growth in both the final post-assessment as well as the transfer-task, even though my reflective journal showed how I felt like my instructional design and role as a PBL tutor were the most effective in the final PBL. Overall, student responses to the transfer task for each PBL scenario were lower than the responses to the student-created diagram for each PBL scenario. Therefore, some students may have difficulty when transferring their knowledge to a different problem scenario. This may have occurred because of lack of time at the end of the PBL for students to develop a deeper understanding of the scientific model under study. My perceptions of PBL as a new PBL tutor show that PBL can be a powerful mechanism for bringing conceptual change; however, I still can improve as a PBL tutor, especially in building skills in creating explanatory models and assisting students in learning how to transfer knowledge to new scenarios.

Throughout this process, I attempted to improve as a PBL tutor and create a more equitable classroom. While themes did not emerge consistently for triangulation, important ideas emerged through my reflections. For example, I grappled with the difficulty of providing too much support to groups or not enough support to groups during the PBL process. It was difficult for groups to develop a hypothesis for the PBL solution if one or more group members expressed misconceptions regarding the concept under study. I also worked to improve the resources available for student research and integrating labs within the PBL learning experience. In addition, gender equality is still an issue within instruction. For example, in the last PBL, one cisgender female student described feeling frustrated in not being about to participate as fully in the final PBL as the other two PBL learning scenarios.

Findings: Research Question 2

Four sources of data were collected to answer my second research question: What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? These data include focus group interviews, a journal maintained by the teacher-researcher, the transfer task completed by students at the end of each of the PBL learning experiences, and evaluations of myself as a PBL tutor by the media specialist, Emily, and her intern, Amanda. I used these four data sources for triangulation for the following emergent themes: actions of the PBL tutor, science as difficult, and risk taking. For the theme of risk taking, patterns were found across two of the data sources, while I found the other themes across at least three of the data sources. Focus group interviews took place at the beginning of the action research study and the end of the action research study. There were 17 journal entries in my research journal written each day of the action research study. The evaluations of myself as a PBL tutor took place three different times throughout the research study. Students engaged in three different PBL scenarios, and I was evaluated as a PBL tutor during each of the three scenarios. This section explores the findings of each of these data collection methods. These data methods were analyzed using emergent codes (Miles et al., 2014).

Actions of PBL Tutor

A theme which emerged through reflection and the emergent coding of qualitative data is that actions of the PBL tutor while implementing PBL may be an important factor in the creation of a more equitable classroom for all learners. Qualitative data from the reflective journal, tutor evaluations, and two focus groups interviews were coded using the emergent categorical code of "actions of PBL tutor." Please see the codebook for a description of this code (Appendix J). During each PBL, I attempted to employ discussion strategies to increase participation across the classroom to create a more equitable science classroom. I used a variety of strategies to increase participation during the PBL investigation including think-pair-shares, Socratic seminars, and white-boarding activities. I used a variety of grouping strategies to mix students into different collaborative groups for each PBL scenario.

Reflective journal. In my journal, I reflected on how there are periods of unequal participation, and how I intervened as the tutor to encourage equal participation from all students. For example, when leading a class discussion about what we know/what we need to know/hypothesis discussion activity during the phases of the moon PBL, mostly male students volunteered to provide answers. I described in my journal:

> I asked each team to raise their hand to share their hypothesis. When this happened, all boys raised their hands—eagerly—to share. After about three boys from different groups spoke, finally, one girl who is confident and often answers questions—Cindy—volunteered to answer. Therefore, I asked a different person to share for the next prompt in an attempt to foster more participation across the classroom. More students who are less likely to willingly volunteer to answer participated in the discussion, including four other female students.

I intervened as the PBL tutor to encourage all students to participate in the class discussion, rather than the few who typically raise their hand to answer questions.

During the first PBL on day/night, I reflected on the unequal participation across groups when I am working with teams to help guide their instruction. I wrote:

> Even while working with groups, one person would volunteer to answer. Also, when working with each group, it would help me if I asked for everyone to contribute in answering questions during the earth/sun demonstration.

As the PBL tutor, I visited each team to speak to the team about their process, research topics, and modeling activities. I noticed the same person would often volunteer to answer my questions. Therefore, I would intervene and say things like "Can I hear from someone else for this question?" and "I would like to hear from everyone in the team."

During the Socratic seminars, students were asked to share their findings and ask higher-level questions to the class to facilitate a whole-class discussion. Each student was provided a Popsicle stick and was required to share at least one time during the discussion. I collected the Popsicle stick after the student spoke to the entire class. During the final PBL on phases of the moon, I described:

> I had a few female students hold onto their Popsicle sticks until the end. One female student was put a bit on the spot as she still had hers and all the students knew … I wanted her to feel comfortable so I just called the Socratic seminar and asked her to write her own question and provide me the answer as a form of participation.

I attempted to hold each student accountable and be active in the learning process through my interventions as the PBL tutor.

PBL tutor evaluations. Our media specialist, Emily, and her student teacher, Amanda, evaluated me. Amanda and Emily both received training in how to use a PBL evaluation tool (see Appendix G). I led this training and communicated with Amanda and Emily throughout the research process to receive feedback and help them understand the PBL process within a middle-level science classroom. During the first PBL on earth rotation, Emily noticed, “You used questioning strategies to redirect and focus groups. All students were encouraged to reason and develop their own hypothesis and formulate questions.” During the second PBL on seasons, Amanda observed, “Love that you worked with students’ answers—you are positive and steer them in the right direction with questions.” On the final PBL about moon phases and moonrise and moonset, Amanda and Emily observed during the Socratic seminar where students discussed their PBL solutions and findings. Emily observed, “Great job letting them explore curiosities, then refocusing on the question at hand.” All of the observations directly relate to how the PBL tutor can guide the instructional process and encourage participation from all students.

Focus group interviews. In addition, the PBL tutor can influence the PBL learning process when placing students into groups. For the first PBL, I placed students into same-gender teams; for the second PBL, I allowed students to choose their groups. In the third PBL, I placed students into mixed-gender groups and attempted to separate friends from one another. During the second focus group interview, I asked the six participants about how choosing teams helped or hurt your learning:

Cindy: My group made a 70.

[Laughter from everyone]

Jordan: Yeah we had to go back and redo it … plus one of our team members was gone, so …

Cindy: That’s true.

Jordan: But we didn’t do too well because we like to talk the whole time.

Cindy: In our defense though, in our defense, well, we could have done better. … I can’t even make an excuse. That was terrible … it depends. It depends on the purpose. We didn't even really look at the rubric. But we were missing a person, so I am going to keep using that as an excuse.

Lauren: I mean, I think it hurt, but then again, we also got a 100. We talked, but we also got our work done. I liked being with my friends, working with them, but I just wouldn't do it again.

Amy: Yeah, I kind of agree with what they said, you just get like too distracted talking to your group. Like, even if you do get your work done, you aren't really comprehending what you are doing.

[Laughter from everyone]

Tess: It is better if you work with people other you don't know a whole lot so you are more focused on what you need to know and they aren't like playing with you, and oh hey that's not right and you are more focused, so yeah, I agree.

Jessica: Yeah, I feel like if I'm with my friends, I can say, "Oh hey that's wrong, do it again," but, when I'm with random person or acquaintance, I can't say oh that's wrong redo it. I'm more like, "Can you look over the points and make sure they are right?"

Cindy: I think that is the only downside of not working with your friends. You don't feel as comfortable, and it's just … I don't know … it's easier with your friends to be like, oh, no that's definitely wrong, as opposed to just if you don't know them as well it's kind of awkward. You just have to push yourself into it.

Becca: I mean I don't know, me and Jessica actually worked together on that one, but I honestly don't remember because we were just talking after we got it done. We got it done quickly and then we just talked.

Tess: It's hard to say this because like everyone likes working with their friends.

In summary, the students discuss the positive aspects of working with their friends in the second focus group interview, including being comfortable talking about whether parts of their project are wrong or right. However, the overall consensus was that it seems to be more effective when the teacher chooses groups. For example, Becca says how she doesn't even remember the project where she was working with her friend. Five of the students discuss how they did not prefer working with the teams that they chose on their own because of becoming distracted or receiving a lower grade.

Using PBL to Make Science Less Confusing

Through analysis of the PBL data, an emergent theme appeared within the corpus: science as confusing. Please see the codebook for a description of this code (Appendix J). The theme emerged across three data sources: the two focus group interviews, the reflective journal, and the student-responses on the transfer task question in the post-assessment. I used the three data sources for triangulation for this theme.

Focus group interviews. During the first focus group interview, I questioned the six student-participants about their feelings towards science in comparison to other students. During the first focus group interview, I asked the participants which subject in school is their favorite subject. Two students said math was their favorite, two students said English language arts was their favorite, and two students said history was their favorite; none of the students said science is their favorite subject. Five of the participants describe science as confusing:

> Jordan: Sometimes in science, it's not all facts, it can be theories that people think because sometimes you don't realize, okay, this is a theory someone made up, and you have so many people that make up these theories, and then like rules of science.

Tess: I definitely agree with you—that is my biggest problem. Also my other biggest problem is thinking outside of the box because with science, you have to really think about how and why these things are happening, when in other subjects, it's that you read something, and that's the way it is, but with science, you have to really get your brain thinking to why its happening, and not what you think is entirely accurate.

Jessica: I agree with Tess because like in English, social studies, and math, it's straightforward, but in science you have to think outside of the box and apply what you learned to certain things like tests … and sometimes it just doesn't click with me.

Amy: I agree with them too, because sometimes in science it can be confusing.

Becca: Because, yeah, with what Amy was saying, sometimes I get really confused because you have to memorize it and think about what you have learned.

The six discussed their opinions about science and how science can be confusing. Only one student, Cindy, who is very strong in science, did not speak about her opinions of science being confusing or not.

During the second focus group with the six cisgender female students, I asked the participants if PBL has helped or hurt their learning and if it was a step in the right direction of creating a classroom of people confident in learning difficult science content. None of the six students said that they disliked PBL or felt that it made them feel less confident.

Tess: Um, yeah, what we have been doing really helps because each subject takes a different type of thinking. I used to be like blocked for science, like yeah I don't really get it, or whatever, it just kinda happens. But, now I have kind of learned how to like think outside of the box, and think of how things might work. So it's kind of changed my thinking process to figure out things that are more complex, like the world.

Amy: Yeah, I think it did help me feel more confident because it made me really think about it, and apply what we have learned, and talking to the class about it because you have to explain what's going on around you.

Becca: I feel like it sticks with you longer when we do the tests we are doing now because honestly, I don't remember as much as I do from the other units like the color unit.

Jordan: I agree with Becca, because, like, for social studies, when we have to remember all of the information for our test, I just remember what I need to know and then I'll go back to forgetting it because I can't remember even the first subject that we did in social studies. I just learn it, take it in, and then I just forget about it. I know that doesn't sound good, but that's okay.

Jessica: I'm starting to like science a lot more now from these PBLs because in elementary school and sixth and seventh grade, we didn't really have a great teacher. I was like, I don't really care about this, I'll do my work, I'll get a good grade, I'll be fine, but like, the PBLs have really helped me understand what is going on and get a better understanding of science.

All six participants describe the PBL learning experiences as positive. One student, Jessica, described liking science more because of the PBL experiences. Two students, Tess and Amy, described the PBLs as being helpful in understanding difficult scientific concepts, Becca and Jordan, described being able to remember the scientific concepts better because of PBL. Amy described PBL as helpful in increasing her confidence in science.

Transfer task. As described in the findings for research question one, the student performance on the transfer task for each of the three PBLs was lower than the performance for the student-created model on the final post-assessment for each PBL. For example, Table 4.7 shows how in the final PBL on the phases of the moon, I identified 23 students as "meets understanding," two as "approaches understanding," and two as "developing understanding." Performance on the transfer tasks was lower, as I categorized 12 student-responses as "meets understanding," 11 as "approaches understanding," and four as "developing understanding." For each PBL post-assessment, student performance was lower on the transfer task than it was on the final model created by the students. The final model was similar to the model created during the PBL learning experience, whereas the transfer task called for students to apply knowledge to a slightly different problem. I described this difficulty in my reflective journal several times with all three PBL scenarios. For example, I write: "The transfer task about the 'phase of earth' was difficult for this class, but was an appropriate challenge."

Reflective journal. In addition, moments appear throughout my journal where students were encouraged to grapple with difficult and sometimes confusing scientific concepts. For example, when hypothesizing about possible solutions to the PBL on moon phases, I described, "Brainstorming hypothesis was a little difficult for this PBL, especially when students still have misconceptions." During the seasons PBL, students may have experienced difficulty when explaining how tilt causes seasonal change:

> The majority of the students seem to realize that distance is not the cause of seasonal change. However, I am having a difficult time getting the students to go

> into depth with their diagrams and PBL solutions. While students are realizing the tilt of the earth is the reason for seasonal change, they are having a difficult time with HOW the tilt causes seasonal change, for example, direct and indirect light and amount of daylight over a year. I keep asking the groups, "WHAT makes the tilt actually cause us to warm up in summer and cool down in winter" as I go from group to group.

In summary, the first focus group revealed insight into the ideas of the students about science as confusing. The transfer task shows how students struggle in the transferring of knowledge to a new scenario. The reflective journal described several moments of having to encourage students to think critically to understand a scientific phenomenon. The second focus group interview showed how some participants expressed how the PBL made science less confusing.

Risk Taking

The theme of risk taking emerged across two different data sources, and even though triangulation did not occur for this theme, risk taking was an important aspect of the PBL process. Triangulation may not have occurred for a variety of reasons; however, it was likely because the design of this intrinsic qualitative study did not isolate this possible pattern before the implementation of the study. During the first focus group interview, I asked the participants how they feel about taking the risk of speaking within their group or in a class discussion. Several of the participants described enjoying speaking within the group, but others enjoy it less:

> Jessica: I don't know … I don't always like speaking in front of the class because I always feel like I'm going to get something wrong.

Cindy: I mean, I don't know, I think you are learning from it. Like you [points to teacher-researcher] are never like, "No. You're wrong. Go to the corner time out." [laughter from group] But, I mean you are not going to get punished for having a wrong thought. I mean we are here to learn about this stuff, so I mean getting things wrong is a part of it, I think.

Jordan: So, I feel sometimes because I like to be a perfectionist, so when I'm told I'm wrong it is a bit embarrassing, and, um, I don't really like getting things wrong, and so I try to fact check it a lot, but when I do know, I answer.

Jessica: I like it, but I also dislike it, but because it's a good way to express yourself, but if you get it wrong of I can just go back and check, but also if you get it wrong it's quite stressful because it's like oh what did I do to get it wrong

Tess: Um I'm the same way, I'm like Jordan, I like getting things right I like to know things that's like facts. But in science when you get things wrong, it's science, no one is always going to be right. Before like everything was invented people had different hypothesis and what not, and it took generations to get things actually right so getting things wrong in science actually might be for the better, not for the worst.

Amy: I don't like to get things wrong, but it's a good learning experience about what you are thinking because you get to know why you were wrong.

Becca: I also don't like to be wrong about stuff because I feel embarrassed when I am wrong, but it does help you to learn from your mistakes.

Four of the student participants—Becca, Allie, Tess, and Cindy—speak about how getting things wrong is part of the learning process and helps "you to learn from your mistakes." Five of the student-participants speak about not liking to be wrong; two of these participants not liking being wrong because of feeling embarrassed.

During the second focus group interview, I asked the participants: Have the PBLs we have done in class made you feel more confident or less confident in sharing your ideas with others?

> Becca: I guess it makes me feel confident if I get a right answer and it's like yeah, I learned that, but it also helps you gain confidence when you get a wrong answer because there is no need to be embarrassed. I can just listen to what they are talking about, and I can just understand it a little bit more, and just keep on and like, no I got that right.
>
> Jessica: I mean sometimes if I know the information really well, but most of the times not really, but I don't want to get it wrong, and someone is like, no, that's not how it works
>
> Amy: Yeah, I agree with Lauren, but it depends on what we are doing and how much you know about it.
>
> Cindy: Yeah I like to just ask a question, because then you can't be wrong, or I just say something I am really confident with. I don't mind being wrong in a small group, but I'll be wrong on my own account. I know I'm probably wrong, I just don't want to be wrong in front of the whole class.
>
> Jessica: I feel the same way as Charlotte.
>
> Tess: It doesn't really matter to me because I like to voice myself. But if I'm wrong, like I am 99.9% I am … [laughter from participants] I don't know it doesn't really matter because I can know the right answer, and I'm just like, oh yeah, you go!

Becca: I just don't really like talking in a large group, but if it's a small group, like Cindy, but if it's a large group, in front of the whole class, I just don't feel as comfortable.

Even after the PBL experiences, the student-participants still grapple with issues of feeling comfortable speaking about their ideas in science, especially when speaking to the entire class. Cindy and Tess both discuss feeling like they are "probably wrong" or being "99.99%" sure of being wrong. Becca and Cindy discuss preferring to talk in smaller groups rather than in front of the entire class. I also asked during the second focus group interview if the PBL experiences have helped the students develop skills that can be used in other areas of their life outside of science class. One student spoke about being able to comprehend something difficult in a short amount of time. Four students—Tess, Amy, Cindy, and Jordan—talk about how working with others was helpful. Amy described how it has helped her with speaking skills: "That is what I was going to say as well. I guess like, speaking, it has made it easier."

The theme of risk taking emerged through the analysis of the PBL tutor evaluations. For example, during one evaluation, Emily wrote, "You still had to really push some of the girls to talk. But they all did eventually!" During the same evaluation, Amanda described, "You were encouraging and students seemed to feel comfortable taking risks." I reflected on this experience in my journal: "Risk taking is something I am hoping for with my female students—really all students—so this is good to hear and may be worth asking the female students at the end of the study." In summary, taking risks was an aspect of the PBL process, especially when encouraging students to speak about their science ideas in both small group and whole class discussions.

Discussion: Research Question 2

Four sources of data were collected for triangulation to answer my second research question: What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? The data include focus group interviews, a journal maintained by the teacher-research, student artifacts from the transfer task, and evaluations of myself as a PBL tutor myself as a PBL tutor conducted by the school's media specialist, Emily, and her intern, Amanda. Through analysis and coding of the data, three themes emerged including science as confusing, actions of the PBL tutor, and risk taking.

Actions of the PBL Tutor

Throughout the entire PBL process, I became more intentional in encouraging participation from all students. In the past, I often relied on those students who raised their hands to answer questions; I occasionally called on people at random, but I have become more focused on creating a more equitable classroom by encouraging participation from all students.

In my reflective journal, I discussed how the cisgender male students tend to dominate the discussion in this class, as they are generally the first students to raise their hand to participate during a discussion. I intervened as the PBL tutor to encourage all students to participate in the discussions by telling the class a different person from the team must speak each time as I hear from each group during class discussions. When I would work with each group as an individual group, one person would often volunteer to answer or speak with me about the topic. I described my efforts in encouraging everyone to speak to me as I met with each team and offered support as the PBL tutor.

During the PBL tutor evaluations, both evaluators described how the actions of the PBL tutor could be used to guide students. For example, Emily noticed how questioning strategies were used to redirect and focus groups and how I encouraged all students to develop hypotheses and questions. Emily stated, "Great job letting them explore curiosities, then refocusing on the question at hand." Even when groups have an idea that is not focused on the problem, positive reinforcement and questioning can be used to guide them in a more appropriate and focused direction.

In addition, placing students in teams has an impact on student learning and performance. The six focus group participants discuss the positive aspects of choosing their own teams, but are in agreement that they got the most out of the PBLs where I chose the teams for the students. I tried a variety of strategies when grouping students into teams. During the first PBL, I assigned students teams consisting of same-gender students. During the second PBL, students were allowed to choose their teams. During the final PBL, I assigned mixed-gender teams. Cindy and Jordan described in the second focus group interview how the lowest grade they received was during the PBL experience where they were allowed to choose their teams. Amy said that their team did well, but that they talked too much. Amy agreed with Lauren and added, "even if you do get your work done, you aren't really comprehending what you are doing." The PBL tutor can make intentional choices in creating groups that could impact student learning and success within the group.

Using PBL to Make Science Less Confusing

The first focus group revealed how many of the student-participants think science is confusing. For example, five of the six participants described feeling confused in science class; only one participant did not speak about feeling confused in science class. The six cisgender female participants entered the PBL learning experiences somewhat disinterested in science; none in the focus-group interview recognized science as their favorite subject. The transfer task from each of the three PBL scenarios shows how students struggle in the transferring of knowledge to a new scenario and demonstrate student performance on a difficult aspect in science class. Student answers to the transfer task were lower than the student-created final model on the post-assessment. The reflective journal described several moments of having to encourage students to think critically to understand a scientific phenomenon.

Misconceptions often made student understanding more difficult, and I provided support in assisting students in the learning of the content. The second focus group interview showed how some participants expressed how the PBL made science less confusing. By the end of the PBL experiences, the six participants in the focus group speak of PBL positively impacting their experiences, by either increasing confidence, liking science more, understanding the material better, or by being able to remember the concepts longer. In summary, there is a possible relationship between the implementation of PBL and helping make science less confusing for students. Giving students support and opportunities to grapple with complex scientific phenomenon and discussing their ideas with others could create a space for developing the skills to understand scientific ideas better.

Risk Taking

Throughout the PBL, I attempted to create a classroom environment where all students feel safe discussing their ideas about science and foster a place where each person feels comfortable taking risks. During the first focus group interview, most (five) of the student-participants spoke of not liking to be wrong when they answer a question or speak during a discussion; four of the student participants spoke about how getting things wrong helps "you learn from your mistakes." While students acknowledged how getting wrong is part of the learning process, the majority of the group feels less comfortable speaking in front of the entire class than in smaller groups. During the second focus group interview, I asked if PBLs have helped them feel more or less confident in sharing ideas with others. Several of the students discussed feeling uncomfortable if they get something wrong. Cindy mentioned not wanting to be wrong in front of the whole class, so she said something that she feels confident about. One student, Amy, described how the PBL has helped her speak in front of others. Several of the students described feeling like they are always wrong when they say something. PBL provided an opportunity for all students to take risks; however, several of the students in the focus group still feel uncomfortable if they get something wrong during class.

During the PBL observations, Amanda and Emily mentioned how the classroom environment seemed like one where students feel comfortable taking risks. In one observation, Amanda observed, "You were encouraging and students seemed to feel comfortable taking risks." In my reflective journal, I described, "Risk taking is something I am hoping for with my female students—really all students—so this is good to hear." For example, during the final PBL, the evaluators observed a whole-class discussion about the moon phase PBL. Emily, one of the evaluators, writes, “You still had to really push some of the girls to talk. But they all did eventually!”

The tutor evaluations and focus group interviews show that there could be a relationship between interventions of the PBL tutor and confidence of cisgender female students; however, this relationship could be explored through future research. A more detailed study of the stereotypical beliefs of all students in regards to gender and education would be beneficial, including a more focused plan to disrupt these stereotypical beliefs and increase self-confidence through focused science pedagogy.

Reflection

This action research study sought to answer two research questions: How does PBL impact the conceptual understanding of students in an earth science class? Then, I explored the findings of the second question: What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? To answer both questions, I conducted an intrinsic case study investigating my perceptions as the PBL tutor while collecting qualitative data. While the two research questions for this action study were individual questions, the data collection process was intertwined with each question as the action research study developed. I found the two questions impossible to separate as I acted as the teacher-researcher in this intrinsic case study. While the two research questions for this action study were individual questions, the data collection process was intertwined with each question as the action research study developed. To answer the first question, I include an in-depth analysis of video blogs created by student-participants, pre-assessments and post-assessments for three PBL learning experiences, and an analysis of student responses to the transfer-task of each post-assessment for the three PBL learning experiences. The results of the data indicated that the use of PBL by the teacher-researcher in an eighth-grade earth science classroom is somewhat effective in fostering conceptual change or conceptual growth for the 27 student-participants. Some students still showed evidence of misconceptions, experienced difficulty transferring knowledge to a new problem scenario, or experienced difficulty in identifying the cause of particular phenomena such as the appearance of the rising and setting of the earth, moon, and stars.

To answer the second research question, I analyzed qualitative data from two focus group interviews with six cisgender female student-participants, a reflective journal I maintained throughout the research process, and six evaluations of myself as a PBL tutor conducted by the school's media specialist, Emily, and her intern, Amanda. I collected and analyzed qualitative data; I used this analysis in the triangulation of the themes of science as confusing and actions of the PBL tutor. In addition, risk taking was an important theme but only appeared in two data sources.

This chapter explored the findings of the two research question of this action research study. Mertler (2014) recommended a four-step cycle to the action research process: planning, acting, developing, and reflecting. Each day of the study, I participated in this cycle as I modified instruction and instructional practices based on daily reflections within my research journal. Chapter 5 describes an improvement plan and implications for future practice based on the findings of this action research study. I have also included a discussion of my perceptions of the limitations of this study within Chapter 5. The improvement plan and implications for future practice are the next steps in the action research cycle.

Chapter 5:

Action Plan and Implications for Future Practice

Chapter 5: Action Plan and Implications for Future Practice includes a discussion of the focus of the study, an overview of the study, a discussion of the major points of the study, an action plan, implications of the findings, and suggestions for future research. In the previous chapters, I have described my experiences while engaging in the action research process as described by Mertler (2014). Mertler argued the action research cycle does not ever truly end, as the teacher-researcher is constantly immersed in cycles of planning, acting, developing and reflecting. Chapter 5 provides an in-depth reflection on the action research process and describes plans for future implementation and changes to my teaching practice.

Focus of the Study

This action research study focused on my perceptions as a new PBL tutor implementing three PBL scenarios with a class of eighth-grade earth science students while attempting to create a more equitable classroom for all students. The identified problem of practice (PoP) for the present action research involved the difficulty I experience as a teacher attempting to teach eighth-grade students abstract science concepts. I have also observed the unintentional marginalization of female students in the science classroom as this environment has traditionally favored male students. The purpose of this action research study was to describe the perceptions of the teacher-researcher while conducting a series of problem-based learning (PBL) scenarios in an eighth-grade earth and space science classroom while attempting to create a more equitable science classroom for all students. I attempted to answer two research questions through the action research process: How does PBL impact the conceptual understanding of students in an earth science class? What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? To answer the first question, the findings and discussions indicate that my implementation of PBL was somewhat effective in developing an evidence-based understanding of the sun-earth-moon system within this class of eighth-grade students. To answer the second question, the discussion and findings indicate the possibility of a relationship between the interventions of the PBL tutor and the development of a more equitable eighth-grade earth science classroom.

Overview of the Study

This study was an intrinsic qualitative action research study, as I described my perceptions as a new PBL tutor implementing a series of PBL scenarios with a class of 27 eighth-grade science student-participants. Evidence of their progress and conceptual growth were used to provide insights into my effectiveness as a PBL tutor. The case study includes myself and the 27 students participants, and two PBL evaluators during an eight-week unit of study on the sun, earth, and moon system. Throughout the study, students were selected using a maximal variation approach in an attempt to showcase different perspectives or levels of understanding and different voices (Fraenkel et al., 2015). Qualitative data were collected to answer both research questions; the data were collected and coded using a priori and emergent codes. The coding process was a form of data analysis as I began to notice themes and patterns within the dataset (Miles, Huberman, & Saldaña, 2014). Inferences and patterns were made from the data and used to develop implications for future practice and research.

A PBL framework developed by McConnell et al. (2017) was used to either create or modify three PBL scenarios for use in an eighth-grade science classroom. Prior to instruction, six cisgender female students participated in a focus group interview to explore their perceptions of the science classroom and for me to attempt to gain insight into potential stereotypical views that may impact their participation within in the science classroom. All 27 students created a video-blog explaining their initial beliefs about the motions of the sun, earth, and moon system and how these motions cause phenomenon on earth. Then, I acted as the PBL tutor and implemented three PBL scenarios over eight weeks while maintaining a reflective journal. During each PBL, I was evaluated by the media-specialist for our school and her intern. I trained both evaluators on how to use a PBL evaluator tool that had been modified to fit the needs of this action-research study. Prior to each PBL, students completed a pre-assessment representation of the phenomenon in an attempt for me to better understand the initial understandings of the 27 student-participants. Following each PBL, students completed a post-assessment representation of the phenomenon in an attempt for me to understand the conceptual changes that have taken place through the PBL cycle. Students also completed a transfer task that asked them to apply their knowledge to a slightly different problem scenario about the topic under study. At the conclusion of all three PBL scenarios, the same six cisgender female students from the first focus group interview participated in a second focus group interview. All 27 student-participants created a final video blog to showcase what they have learned about the three PBL scenarios.

Throughout this process, I became more confident using the McConnell, Parker, and Eberhardt (2017) PBL framework. PBL allows for inquiry, problem-solving, modeling, and discussion within the science classroom, thus incorporating a variety of other educational strategies within the PBL umbrella. I grappled with the balance of providing resources and assistance to students while also allowing opportunities for groups to explore their particular curiosities. I became more aware of voice within the science classroom, whether it was my voice, the voice of students who tend to speak more, and the voice of students who tend to speak less. Through the use of PBL, I have attempted to become a more effective PBL tutor, while also becoming more aware of the subtle issues that impact science instruction such as stereotypical beliefs and levels of participation within the classroom learning environment.

Discussion of Major Points of the Study

The first research question asked: How does PBL impact the conceptual understanding of students in an earth science class? Through the use of a priori coding of student-created video blogs, pre-assessment and post-assessment representations created by student-participants, and an analysis of student-responses to the transfer task, there are implications that implementation of PBL in this earth-science classroom was somewhat effective in the development of an understanding of an evidence-based scientific model of sun, earth, and moon interactions. Overall, students displayed evidence of growth in their understanding, as shown across all three data sources. However, student-performance on the transfer task was lower for each of the three PBL scenarios in comparison to student-performance on the final post-assessment representation. Therefore, some student-participants may have experienced difficulty when transferring new knowledge to a different situation or scenarios.

The second research question asked: What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? In an attempt to answer this question, I analyzed data from two focus group interviews, observations by the media specialist and her intern for each of the three PBL scenarios, student responses to the transfer task question on the post-assessment, and my descriptions from a reflective journal maintained throughout the research process. Through the analysis of these data, themes and patterns began to emerge from the corpus, including actions of the PBL tutor, science as confusing, and risk taking. There is a possible relationship between the interventions of the PBL tutor and a more equitable science classroom; however, a more focused research study is needed to validate these findings. Each data source revealed the PBL tutor could intervene to encourage participation from all students through focused and intentional questioning and the design of lessons and discussion opportunities. In addition, the focus group interviews revealed how many of the student-participants in the focus group feel that science can be confusing, which could impact performance in the classroom, as seen on the transfer task question. The third theme of risk taking emerged—PBL could create an environment that encourages students to take risks within the science classroom.

Discussion of Changes

I created this study as a qualitative action research study using an intrinsic case study design. Qualitative data were collected and coded in an attempt to answer two research questions. The student-participants were 27 students in one eighth-grade earth science classroom. During the study, students were selected to showcase a variety of scenarios to capture events and perspectives from within the classroom learning environment. I used six data collection methods during this action research study: video blogs, pre-assessments and post-assessments for each PBL, transfer tasks for each PBL, a reflective journal, three PBL tutor observations, and two focus group interviews.

If I could conduct this study in the future, then I would allow more time during each PBL to support the transferring of knowledge to a new scenario in the transfer task. Students seemed not to have enough time to develop a rich understanding of the material, as shown by student-performance on the transfer task. Therefore, more time and support needs to be provided within the classroom to assist students in their ability to transfer learned content to a new scenario.

I would also make changes to my methodology for the second research question. At the beginning of the study, I was hoping to disrupt stereotypical gender norms within the classroom. However, my main effort became to create a classroom where more students are participating and involved in the classroom, rather than targeting specific stereotypes as I was at a loss at how I could reduce these stereotypes within my classroom. This is likely because I did not include a focused intervention to address specific stereotypical beliefs in my original research design. From the first focus-group interview, I was astonished at the stereotypical beliefs discussed by the six cisgender female students. While I targeted instruction create a more inclusive classroom, these beliefs of stereotypes are likely still be held by student-participants within this study. The first focus group interview revealed all six cisgender female students believed girls tend to be better at English, while boys tend to be better at math. I may have been able to better isolate stereotypical beliefs through the use of individual interviews with each student-participant. If I could conduct this study again, I would conduct one on one interviews with student-participants to gain greater insight. In the future, greater action needs to be taken to address stereotypes that may be impacting student beliefs and performance within the science classroom.

In the process of answering Research Question 2, a potential causal relationship began to emerge from the data. While triangulation was used to show the importance of interventions of the tutor, a more detailed and focused study is needed to show causation between the interventions of the PBL tutor and a more inclusive science classroom for all students. Miles, Huberman, and Saldaña (2014) argued developing a causal network must be planned from the beginning of the study for data collection to build towards this network. Through reflection of the entire dataset, I noticed the pattern and theme of actions of myself as the PBL tutor and how these actions led to increases in participation from all students. I also noticed how the six cisgender female students discussed their positive feelings towards the PBL scenarios at the end of the action research study. A more detailed analysis of the data throughout the collection process could have helped me develop this causal pattern; however, I did not recognize this emergent pattern until after I collected data. If I could conduct this action research study again, then I would be more aware of causal and recurrent phenomena within the data collection process in an attempt to more thoroughly develop this possible causal network. In addition, the theme of risk-taking emerged in the analysis of the data to answer the second research question across two data sources. If I had predicted this theme prior to the beginning of the study, then I could have designed focus group questions and journal entries to more effectively isolate patterns related to risk-taking.

Action Plan

Mertler (2014) argued the importance of the development of an action plan following the implementation of action research. An action plan provides an opportunity to reflect on the outcomes of the action research process and focus on the next steps for implementation within the classroom. I have developed a two-step action plan to continue the process of improving my teaching practice as a PBL tutor and to continue to create a more equitable science classroom for all students.

Action Plan: Step 1

Purpose. The primary research question was to determine my perceptions of implementing PBL with 27 student-participants in an eighth-grade science classroom. The findings indicated my implementation of PBL within the classroom might lead to conceptual growth. However, some students still have difficulty transferring learned information to a new scenario, and some students still have difficulty developing explanatory models for a phenomenon. The purpose of Step 1 of this action plan is to find and implement strategies to increase student ability to transfer learned information to new scenarios and to find and implement strategies to increase student ability to create explanatory models for scientific phenomena.

Objectives. I have described the desired outcomes for Step 1 through the following four objectives:

1. I will plan and implement research-based lessons that have been found successful in increasing student ability to transfer studied science content to a different or new scenario. I will also provide time and support within the classroom to improve the transfer-ability of future students.
2. I will plan and implement research-based lessons that have been found successful in increasing student ability to develop explanatory models for scientific phenomena.
3. Students will show increased performance on transfer task questions.
4. Students will show increased performance in developing explanatory models of scientific phenomena.

Example strategies. The findings of the action research study show how students may have difficulty transferring science knowledge learned in class to slightly different and new problem scenarios. To meet the first objective, I will use prior research to identify strategies to improve the transfer ability of students. For example, Piksööt and Sarapuu (2014) conducted a study investigating ways to enhance the ability of secondary school students in transferring knowledge within complex science domains. The researchers used question prompts within two web-based models in a molecular genetics unit. Students were asked to construct a biological process by altering objects within the model. The experimental group was asked to answer a question following the modeling activity to facilitate the transfer of knowledge; the control group worked without the different question prompts. The researchers found the intervention of students supported by the additional question prompts had a “statistically significant influence on the students’ knowledge transfer as indicated by their answers” (p. 213). The authors recommended applying appropriate questioning strategies to guide “attention to the relevant features of the depicted process while studying a complex subject” (p. 213). Therefore, I will employ focused questioning strategies within model-based instruction opportunities to help guide students to the aspects of the model that could aid students in transferring knowledge to different situations in an attempt to increase the transfer ability of students within my classroom.

To meet the second objective, I will plan and implement model-based instruction for future eighth-grade science units in an attempt to increase student performance in developing explanatory models of scientific phenomena. Dolphin and Benoit (2016) conducted a qualitative study exploring the development of mental models of students during a plate tectonics unit. Five women were involved in the qualitative case study. The class included 40 students and was 95% female in a college-level undergraduate geology course. The instructor used a series of four lessons. Each day consisted of an essential question, historical interludes related to plate tectonics, inquiry activities, and model-based learning. The researchers coded mental modeling into descriptive codes and explanatory codes. The authors define descriptive codes as codes that “tells what” (p. 282) and explanatory codes “tells why” (p. 282) for knowledge. The authors explain the difference between the two codes:

> Where descriptive knowledge relies on direct observations (some coasts have deeper earthquakes), explanatory knowledge relies more on reasoning, prior

> knowledge, and phenomena that are not necessarily directly observable (deeper earthquakes result from subduction). (p. 282)

The researchers found that the majority of the mental model building by students was descriptive as descriptive claims outnumbered explanatory by 4.7 to 1. The authors discussed how the participants in the study were college age, but their last experience with plate tectonics instruction was in seventh grade and was mostly lecture-based. Many of the students expressed misconceptions as students described continents moving around the earth and crashing into one another. Another student represented spaces between blocks as actual space between plates. The researchers observed that the incoming mental models of the students were incomplete, and this may "be more the rule than the exception" (p. 286–287). Therefore, students are recommended to engage in modeling activities where they are provided time to develop an understanding of the model. For example, students should answer questions that ask "what" instead of "why" or "what if" in the beginning stages of analyzing a model. Then, the instructor should add depth and difficulty to each following question. The researchers also recommended both small group and full class discussion about the facets of a model to help create "the trajectory for developing a foundation for the desired explanatory aspects" (p. 287). The researchers concluded:

> it is not enough to ask students if they understand the concept, but to ask how they understand the concept. The latter can tell us about student thinking, and whether we have developed useful mental models. (p. 291)

Therefore, when implementing model-based instruction and PBL in the future, I will continue to implement small and whole class discussion and use assessment strategies to gain insight into how students understand the concept to better infer their thinking processes in an attempt to help students develop explanatory mental-models of complex scientific phenomena.

Action Plan: Step 2

Purpose. The secondary focus of this action research study was to create a more equitable science classroom for all students while disrupting gender stereotypes that may be present in the classroom. Throughout the action research study, I used a variety of strategies to increase participation from all learners. However, I believe that my efforts were ineffective in addressing stereotypes within the classroom that may impact learning. Therefore, I will use research-based strategies to attempt to isolate and disrupt these strategies in my future practices as a middle-level science educator.

Objectives. There are two objectives for the second step of the action plan for this action research study:

1. Determine stereotypes that impact science instruction and disrupt stereotypes that impact science instruction.
2. Create a culture of learning that promotes risk-taking within the classroom

Example strategies. To determine gender stereotypes that are present, I will implement a survey based on a research study conducted by Kurtz-Costes, Copping, Rowley, and Kinlaw (2014) to determine gender stereotypes believed by students within my classroom. The authors used five-point Likert scale items to assess beliefs of children about how boys and girls perform across a variety of domains. The study by these authors used items that assessed the stereotypes of the child and the child's beliefs about adult stereotypes for mathematics, science, and verbal skills. For their study, the researchers found the data reflected a stronger belief in the traditional stereotype holding boys better than girls within the domain. Following the determination of stereotypes across the classroom using a survey, I will focus instruction in a way to disrupt these stereotypes to create a more equitable science classroom for all students. The survey will be provided again following instruction to see if perceptions of stereotypes have changed.

Heilbronner (2009) recommended a series of strategies to support female students in the middle-level science classroom. Heilbronner reflected about her observations of her classroom as a middle-level science teacher:

> If I were completely honest with myself, I would have to say that while the boys in my class were excited and interested in science, many of the girls were demonstrably less so. They remained in the shadows, letting the boys run the labs and then performing the "grunt" work of the writing the lab reports and cleaning up. (p. 46)

Her observations transcend into my own classroom and the observations and interactions I have with female students in the science classroom. Halpern et al. (2007, as cited in Heilbronner, 2009) listed five research-based recommendations for increasing interest and achievement of female students in science:

1. Teach students that academic abilities are expandable and improvable.
2. Provide prescriptive, informational feedback.
3. Expose girls to female role models who have succeeded in math and science.
4. Create a classroom environment that sparks initial curiosity and fosters the long-term interest in math and science.
5. Provide spatial skills training.

In an attempt to disrupt gender stereotypes that may be present in the classroom, I will employ these five strategies to continue to build a more equitable science-classroom for all students.

In addition, the classroom could become a more equitable space through the implementation of complex instruction (CI) strategies. Cohen, Lotan, Scarloss, and Arellano (1999) discussed how cooperative learning creates situations where groups may exclude those who are potentially socially isolated or lower achieving. The actions of the teacher can work to ensure all group members are active and influential within the group. CI calls for educators to use “cooperative group work to teach at a high academic level in diverse classrooms” (p. 1). Teachers pay attention to group dynamics and are aware of unequal participation. Teachers employ strategies to address specific status problems within groups. One method is to have tasks that are open-ended and uncertain, similar to problem-based learning, where there is no right answer. These types of tasks “increase the need for interaction since they force students to draw upon each other’s expertise and repertoire of problem-solving strategies” (p. 2). The teacher can also provide tasks that call for multiple different types of ability, allowing the teacher to isolate different strengths of students outside of traditional academic content. Even within these open-ended and multi-ability types of tasks, inequalities can emerge within group work. Status characteristics can become part of the expectations of group members, where high-status students have higher expectations and low-status students have lower expectations. Often, “these expectations for competence are held by teachers, classmates, and the students themselves” (p. 5). These expectations may result in students being ignored or not given equal access to materials or a turn in the activity. Students who are popular or are expected to be good at school "have greater access to materials, and are more influential in group discussions" (p. 5). A possible solution is to create a variety of expectations for each student, and within the group, team members must recognize that all contributions for all group members are needed for the entire group to be successful. The teacher can intentionally work to change the opinions of the students by specifically and publicly acknowledging the skills of students marginalized by the group.

In addition, the classroom culture should promote learning and risk-taking. The teacher should establish this culture from the very beginning of the academic school year. Establishing a constructivist classroom is not merely implementing discrete instructional practices; "it is a coherent pattern of expectations that underlie new relationships between students, teachers, and the world of ideas" (Windschitl, 1999, p. 752). A classroom culture consists of the beliefs and norms that make up everyday life within a classroom. The teacher must connect multiple facets of the classroom environment to support a constructivist classroom. Before the teacher implements constructivist pedagogy in the classroom, the classroom culture must be one that will support this type of learning, and risk-taking may not occur.

Implications for Future Practice

Through this action research study, several implications for future practice and future studies have emerged. More time needs to be given within each PBL to increase student performance on each transfer task. A study over a larger amount of time and with a greater number of students is needed to explore the findings of this study in greater detail. This study found that there could be a relationship between the interventions of the PBL tutor and the disruption of stereotypes within the classroom. I also found that PBL may lead to a greater conceptual understanding of complex science concepts. However, this is a local study with a small group of students and is not generalizable to a larger population.

In addition, students described positive feelings about PBL for a variety of reasons. Several female students reported an increase in confidence in science, more likely to take risks, being able to remember concepts longer when learning through PBL, and liking science more as a result of PBL. A future study could investigate the impact of PBL on the perception of students of science, long-term memory, or confidence. Future research could explore several possible research questions:

1. What strategies can impact student ability to transfer science content to a new scenario?
2. How can gender stereotypes be disrupted within a science classroom?
3. How does PBL impact risk-taking within the classroom?

These questions could be explored using a quantitative or mixed-methods experimental design where the action researcher uses surveys and interviews to gain insight into the questions.

The focus group interviews with the female students revealed a wide variety of stereotypical views of the student population that I did not expect. For example, many of the student participants spoke about believing females are generally better at English, and boys are generally better at math. A targeted study to isolate these stereotypes in the middle school climate could be beneficial for future research, as well as ways to directly address these stereotypical beliefs in the classroom. While I attempted to create a more inclusive environment for all students, I likely fell short of what this entire student population may need for greater inclusivity across subjects. A new research question could be: How do stereotypical beliefs impact the perception of students in a middle-level science classroom? This study could use a case-study framework similar to the design used in this study.

Conclusion

The problem of practice addressed in this research study was the challenge I experience teaching abstract science content in an eighth-grade science classroom; in addition, I also have observed the impact of gender stereotypes within science classroom and sought to disrupt these stereotypes to create a more inclusive classroom for all students. In an attempt to find a solution to my problem of practice, I asked two research questions: How does PBL impact the conceptual understanding of students in an earth science class? What are the perceptions of the teacher-researcher while conducting a series of PBL scenarios and attempting to create a more equitable eighth-grade earth science classroom? To answer these questions, I collected data through focus group interviews (Appendix H and I), student-created video blogs evaluated with a teacher-created rubric (Appendix C and D), pre-assessments and post-assessments for each PBL learning scenario (Appendix D), a reflective journal maintained throughout the research process (Appendix F), and PBL tutor evaluations (Appendix G). Throughout the study, I implemented PBL pedagogy modified or created using a PBL framework developed by McConnell, Parker, and Eberhardt (2017) (Appendix A). There were 27 student-participants involved in the study.

To answer the first research question, I analyzed qualitative data from student-created video blogs, student responses for each pre-assessment and post-assessment for three different PBL scenarios, and student-response for the transfer task item for each PBL scenario post-assessment. A teacher-created rubric was used to evaluate each student artifact. Then, I coded the data through an a priori coding scheme based on the teacher-created rubric (Appendix J). The analysis revealed that PBL is somewhat effective in encouraging conceptual growth on complex science concepts, but students may have difficulty transferring learned content to new and different problem-scenarios.

To answer the second research question, qualitative data were analyzed from two focus group interviews, three evaluations of myself as a PBL tutor by two evaluators, an evaluation of the student-responses on the transfer task question, and the reflective journal maintained by myself as the action-researcher throughout the study. I coded this data through an emergent coding scheme (Appendix J). The participants in the study were me, 27 students in an eighth-grade classroom, our media specialist, Emily, and her intern, Amanda. Six female students from the larger class participated in two different focus group interviews. Three themes emerged through the coding of qualitative data: actions of the PBL tutor, science as confusing, and risk taking. Qualitative analysis revealed that there might be a relationship between interventions of the PBL tutor and a more equitable science classroom for all students; however, a more rigorous study is needed to confirm these findings.

My reflections through the action research process have lead to a much deeper understanding of the McConnell, Parker, and Eberhardt (2017) and have helped make me a more confident and reflective PBL tutor. I am more aware of the levels of participation across the classroom and have realized that my actions as a teacher may unintentionally serve some students more than other students. Through this action research study, I have become a more inclusive teacher, as I seek opportunities to increase participation in discussion and class activities from all students. I am also more aware of voice in the science classroom and now continuously seek opportunities to promote and encourage all students to use their voice during science class. I developed an action plan from the results of the action research study. The first step of the action plan seeks to find and implement strategies to increase student ability in developing and using explanatory scientific models, as well as finding ways of increasing student ability in transferring science knowledge to new scenarios. The second step of the action plan seeks to identify specific stereotypes that may impact instruction and implement focused interventions to disrupt these stereotypes in an attempt to empower all students and create a classroom culture that promotes risk-taking. Through focused pedagogies, instructional strategies, and interventions, the teacher may be able to serve as a vehicle to disrupt gender stereotypes and other inequities that continue to marginalize students.

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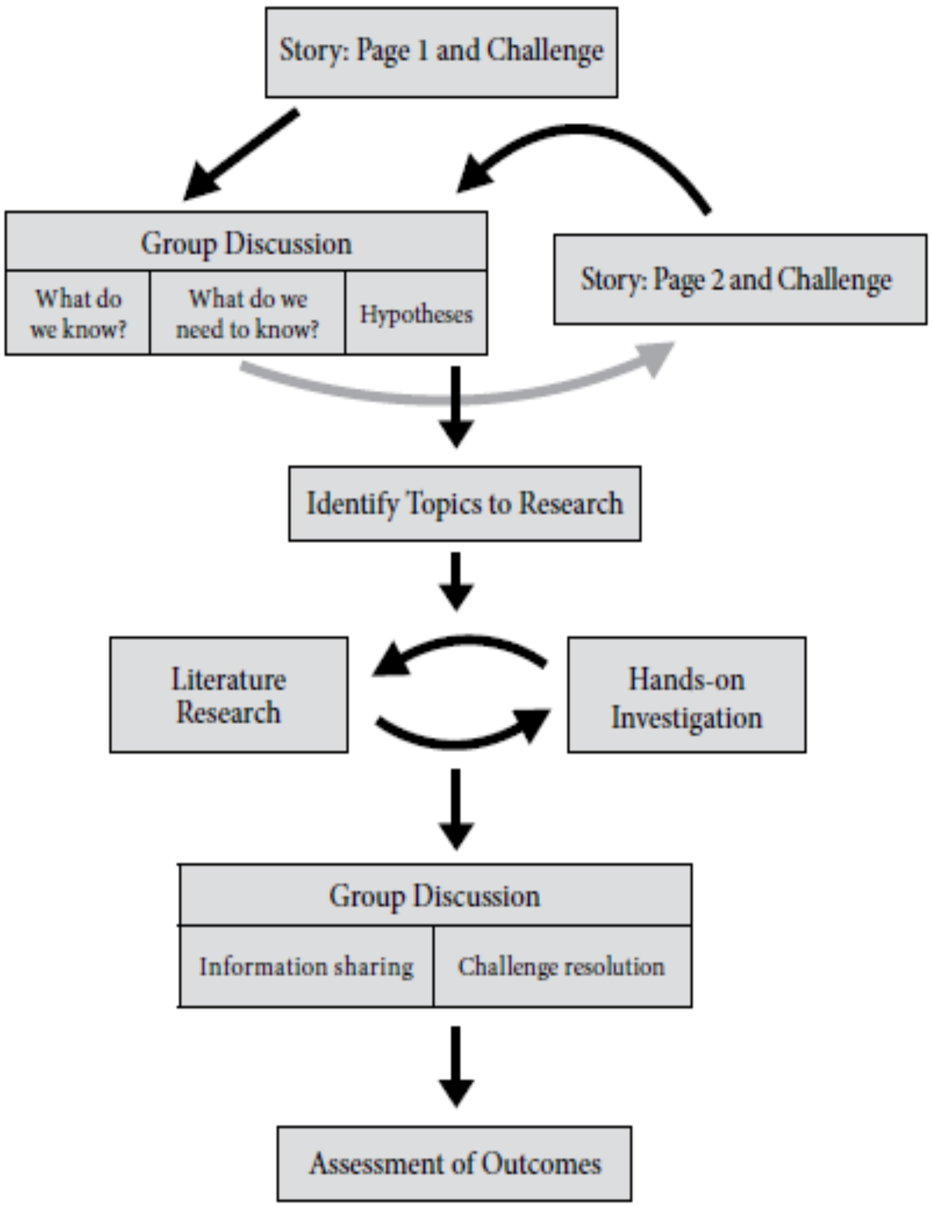
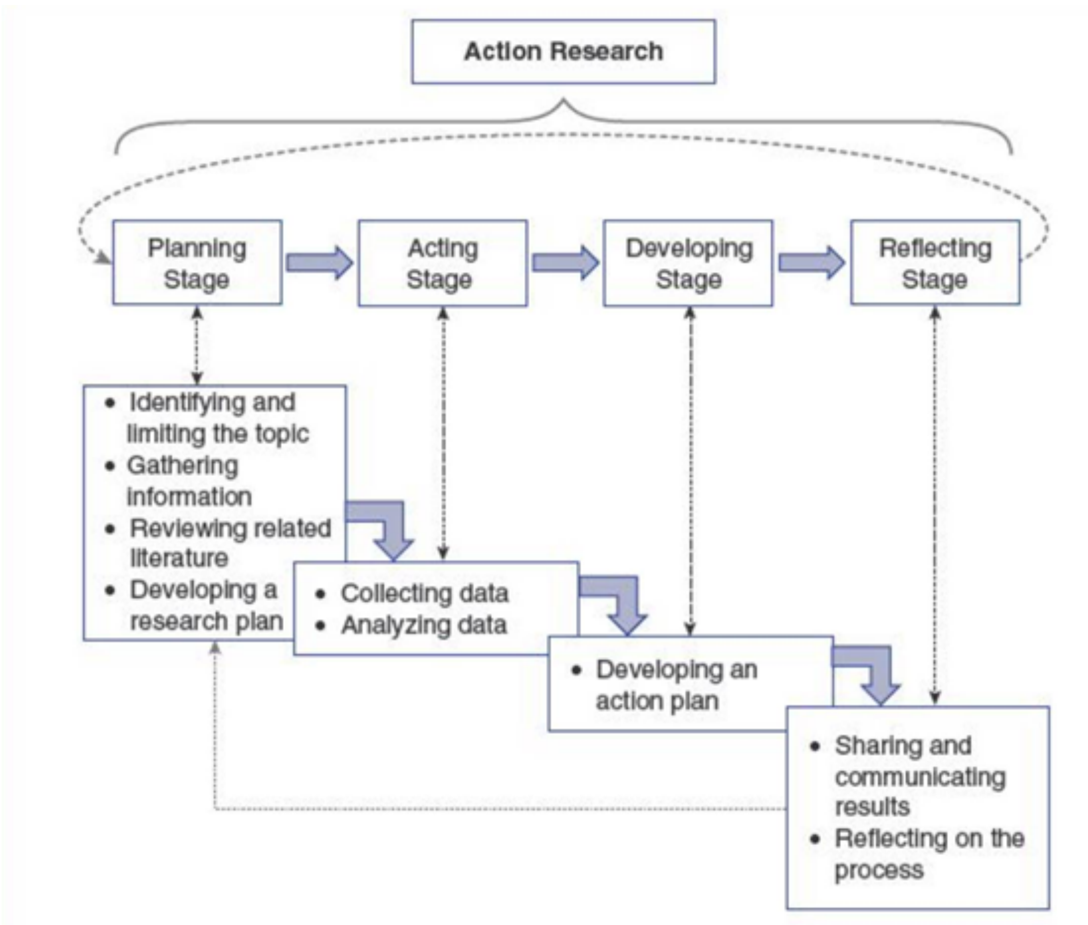
Appendix A:

McConnell, Parker, and Eberhardt's (2017) PBL Framework



Appendix B:

Mertler's (2014) Action Research Process



Appendix C:

Rubric for Evaluating Student-Created Pre-Assessment Videos

	Developing Understanding	Approaches Understanding	Meets Understanding
Earth - day and night	• Student shows that day and night is caused by the revolution of earth around sun • Student shows that the sun goes around the earth or all objects revolve in a path together • Diagram does not explain phenomenon observed in video	Diagram shows earth rotating, but does not relate image to sunrise/sunset	• Rotation of earth causes the apparent rising and setting of sun • Earth rotation takes approximately 24 hours causing a 24 hour day/night cycle • Daytime occurs on the side of the earth facing the sun and nighttime on the side of the earth away from the sun • Position of sun in sky varies throughout the year due to the 23.5 degree tilt of earth
Moon - rise and set	• Diagram does not explain how rotation of earth causes moonrise and moonset • Student shows that the moon goes around the earth every day	Diagram shows earth rotating, but does not relate image to moonrise/moonset	• Rotation of the earth causes apparent rising and setting of moon • Moon's orbit is at a 5 degree tilt relative to the earth and varies in position relative to the sun • The moon can be visible during the day depending on its location in its orbital path around the earth
Apparent motion of stars	• Diagram does not explain the apparent motion of the stars • Diagram shows stars revolving around earth	Diagram shows earth rotating, but does not relate image to stars appearing to rise and set	• The stars appear to rise and set due to the rotation of the earth • The north star is directly above the north pole, therefore it appears to stay stationary while the other stars appear to rise and set • Latitude has an effect on the position of the sun, moon, and stars visible on earth
Direction of earth's rotation	Diagram shows no direction of motion of the sun, earth, and moon	Diagram shows earth rotating, but direction is not correct	Demonstrates the earth rotates to the east causing the rising of the sun, earth, and stars to appear in the east and setting in the west

Appendix D:

Rubric for Evaluating Student-Created Representations

	Developing Understanding	Approaches Understanding	Meets Understanding
Earth Rotation (PBL One)	• Student shows that day and night is caused by the revolution of earth around sun rather than rotation of Earth • Student shows that the sun goes around the earth or all objects revolve in a path together	Diagram shows earth rotating, but does not relate image to day and night or sunrise and sunset	• Rotation of earth causes day and night • Earth rotation takes approximately 24 hours causing a 24 hour day/night cycle • Daytime occurs on the side of the earth facing the sun and nighttime on the side of the earth away from the sun • Earth rotates on a 23.5 degree tilt relative to ecliptic plane • Earth rotates to the east or counterclockwise
Seasons (PBL Two)	Does not relate seasonal change to the tilt of the earth	Relates seasons to tilt, but does not explain how tilt causes seasonal change (missing 2-3 requirements from the meets expectation category)	• Clearly shows tilt as cause of summer and winter • If the northern hemisphere is toward the sun, it's summer; if it's tilted away from the sun its winter • Student relates tilt to amount of daylight a location receives • Student relates tilt to direct and indirect sunlight
Phases of Moon/ Rising and Setting of Moon (PBL Three)	Model incorrectly represents the phases of the moon caused by the relative positions of the earth, moon, and sun and the rising and setting of moon	Model represents the phases of the moon caused by the relative positions of the earth, moon, and sun, but information may be lacking or underdeveloped (2 or more components missing)	• Model shows how moon phases are caused by relative positions of earth sun and moon • Moon revolves around earth every month • Correct location of full moon is represented • Moon rises and sets because earth rotates

Appendix E:

Teacher-Created Rubric to Evaluate Student Transfer Task Response

	Developing Understanding	**Approaches Understanding**	**Meets Understanding**
Transfer Task	Student answers transfer task questions incorrectly	Student responds to transfer task questions, but explanation is either not thorough or has 2-3 errors	Student thoroughly responds to each application question.

Appendix F:

Journal Template Used in Action Research Study

<u>Journal Template</u>

Every other day, focus on conceptual understandings of student OR observation of participation based on student gender.

Date: Lesson overview/title:

Observations related conceptual understanding of students:

Observation of participation based on student gender:

Appendix G:

PBL Tutor Evaluation Adapted from De Grave, Dolmons, and Van Der Vleutan's (1999) Evaluation Tool

Tutor: Teaching unit: Date:
The tutor's contribution: Makes learning uncertain (1) Optimally promotes learning (4)

1. **Problem analysis**			Rating	Explanation
Defining the problem	Does not make the group define the problem	Ensures the group defines the problem and raises relevant questions		
Prior knowledge	Does not encourage students to apply prior knowledge	Stimulated students to exploit prior knowledge		
Links	Leaves the group to enumerate / make a list of acquired knowledge / concepts	Encourages students to regroup acquired knowledge/concepts and schematize them		
In-depth analysis	Inappropriately interrupts group to seek or give information, without considering group's own reasoning	Encourages students to reason and develop their own hypotheses		
Structuring/synthesizing	Allows detailed discussion of minor or irrelevant points	Helps the group to structure its reasoning and to summarize or synthesize when appropriate		
Time Management	Poor time management	Ensures all aspects of problem discussed within allotted time frame		
2. Self-directed learning			Rating	Explanation
Learning	After analyzing the	Helps groups to formulate		

objectives	problem, does not help group to formulate its own questions/objectives	its own questions/objectives and advises on information required		
Resources	Does not discuss appropriate sources of information	Discusses sources of information appropriate for the objectives		
3. Group dynamics			Rating	Explanation
Working atmosphere	Reacts in a negative manner to students' errors	Establishes a working atmosphere that encourages student participation		
Student participation	Accepts no-contributing students	Ensures that all students participated		
Group regulation	Does not help the group manage inappropriate student behavior; dominant student, no-contributing student	Helps the group manage inappropriate student behavior		
4. Gender			Rating	Explanation
Female students	Do not appear to be actively engaged in problem-solving discussion focused on PBL	Appear to be actively engaged in problem-solving or discussion PBL		
Male students	Do not appear to be actively engaged in problem-solving	Appear to be actively engaged in problem-solving or discussion focused on PBL		

Notes:

Appendix H:

Focus Group 1

Date: **Place:**	**Interviewer:** **Interviewees:**

What are your favorite subjects in school?

What are your favorite types of activities when we are in science class?

What makes science class difficult for you?

What makes science class easier for you?

What types of activities help you understand science concepts?

Do you prefer working alone or working in groups?

Can you think of a moment where something really 'clicked' for you in class - any class -… what led to that moment?

How does talking about science ideas help or hurt your learning?

When you know an answer to a question asked in class, are you likely to raise your hand and answer? Why or why not?

What do you do if you do not understand something in science?

Do you prefer working in all-female groups or groups mixed of males and females?

Does anything change when you work in teams with boys?

How do you feel when speaking to the entire class during discussion?

Do you feel comfortable enough to ask for help if needed? Why or why not?

During group work, do you feel confident in sharing your ideas with other kids in your group?

Do you like to raise your hand first when we are talking as a whole group, or do you often wait until later in the discussion to raise your hand? Have you noticed or thought about this before?

If you get something wrong during a discussion, how do you feel? Is there anything I can do differently to offer support in these moments?

Do you think myself or any of your teachers give preferences to girls or boys?

Are there any subjects in schools where you think boys do better than girls?

Are there any subjects in school where you think girls do better than boys?

How do you feel if you make a mistake in class?

Could you see yourself as a scientist one day?

Is there anything important from this discussion that you think I should know?

Appendix I:

Focus Group 2

Focus Group Two

Date: **Place:**	**Interviewer:** **Interviewees**

Over the past 8 weeks, we went through three Problem Based Learning scenarios on Earth Rotation, Seasons, and Phases of the Moon.

What kinds of things did you like about learning through these Problem-Based Learning Scenarios?

What kinds of things did you not like about learning through Problem-Based Learning Scenarios?

What kinds of things were difficult about the PBLs scenarios?

What kinds of things were easy about the PBL scenarios?

Before each PBL, I asked you to create a representation/drawing of the phenomenon, like why we have seasons or phases of the moon. How did this help or hurt your learning?

After each PBL, you were given your original diagram back and asked to reflect on your original understanding. How did this help or hurt your learning?

Let's talk about teamwork for each of the 3 PBLS. I have questions about group-work for all three: earth rotation, seasons, and phases of the moon.

During the PBL, you worked in teams. The first PBL on earth rotation, I picked your teams and made the teams of all female students and all male students. How did this help or hurt your learning?

The second PBL on seasons, you chose your teams. How did this help or hurt your learning?

The third PBL on phases of the moon, I selected your teams and made the teams mixed-gender. How did this help or hurt your learning?

After each PBL, we participated in a socratic seminar. I asked that each person say something to contribute to the seminar and held people accountable by collecting popsicle sticks. How do the Socratic Seminars help or hurt your learning?

Do you feel comfortable speaking in front of the class during the seminar? Why or why not? Do you prefer multiple-choice tests or the way I have been testing you during the PBL? Which helps your learning the most?
Do you see yourself as a scientist one day? Why or why not? Have the PBLs we have done in class helped you feel more confident in sharing your ideas about science with others? Have you developed any skills while we have been working on these PBLs that may help you in other areas of your life or in future academic pursuits? Do you feel like you have developed a better or worse understanding of the motions of the sun, earth, and moon following these PBLS? Did the PBLs help you feel more confident discussing and sharing your ideas with your peers after these PBLs? Why or why not? Did the PBLs help you feel more confident in solving difficult problems? Why or why not? Do you feel like the resources for the PBL were organized and easily accessible? How could this be improved? Are there any skills that you have gained from working on PBLs that can help you in other classes or areas of your life? What suggestions do you have for me when I lead these types of PBL activities with students in the future? I hoping that you leave this experience empowered in your ability to learn challenging science content and feel confident in sharing your ideas and reasoning with others. Do you think that these learning scenarios have been a step in the right direction? Why or why not?

Appendix J:

Codebook

Code	Code Type	Theme	Definition	Example
Rotation Developing Understanding	A Priori	Assessment	Student demonstrates misconceptions or lack of conceptions of earth rotation and apparent rising and setting	"I drew the earth, moon, and sun at day time and at night time. When it's day time, the moon is not blocking the sun"
Rotation Approaches Understanding	A Priori	Assessment	Student includes a developed representation showing some of the components of a scientifically accepted, evidence-based model of day/night, however, several components may be missing.	"Student shows motion of rotation and revolution, but does not clarify which causes day/night"
Rotation Meets Understanding	A Priori	Assessment	Student includes the necessary components of a the scientifically accepted evidence-based understanding of the rising and setting of sun, moon and stars due to rotation of earth	Student includes a highly detailed diagram including tilt of earth, rotation, rising and setting of the different objects in space.
Seasons Developing Understanding	A Priori	Assessment	Student demonstrates misconceptions or	"The earth is moving around the sun and when its further away from the

			lack of conceptions about seasonal change on earth.	orbit its winter and when it's closer its warmer"
Seasons Approaches Understanding	A Priori	Assessment	Student includes a developed representation showing some of the components of a scientifically accepted, evidence-based model of seasonal change, however, several components may be missing.	"When the axis is tilted towards the sun it is summer for the north equator but when it is pointed away it is winter for the north equator" However, important components like length of daylight hours or direct/indirect light may not be included.
Seasons Meets Understanding	A Priori	Assessment	Student includes the necessary components of a the scientifically accepted evidence-based understanding of seasonal change	Student writes "as the sun moves around the earth, different areas get direct and indirect sunlight, causing seasons." She shows the earth revolving around the sun with tilt relating to winter/summer and direct/indirect sunlight.
Moon Phases Developing	A Priori	Assessment	Student demonstrates misconceptions or lack of conceptions about moon phases	"As the moon orbits earth, it goes 'behind' earth and away from the sun's rays, causing the new moon"
Moon Phases Approaches	A Priori	Assessment	Student includes a developed representation showing some of the components of a scientifically accepted, evidence-based model of moon phases, however, several components may be missing.	"Moon phases are caused by our rotation and the moon's rotation. We see different phases also depending on where we are on the earth and how we are seeing the moon on its rotation."

Moon Phases Meets	A Priori	Assessment	Student includes the necessary components of a the scientifically accepted evidence-based understanding of moon phases	"We have moon phases because one side of the moon is lit up by the sun, but we don't always see the part that is lit up." Student draws path of moon's orbit around the earth.
Transfer Task Developing	A Priori	Transfer Task	Student answers transfer task questions incorrectly	Student writes, "the earth phases would have been waxing crescent" and draws the moon in a waxing gibbous phase.
Transfer Task Approaches	A Priori	Transfer Task	Student responds to transfer task questions, but explanation is either not thorough or has 2-3 errors	Student draws the earth as a waxing gibbous, which is correct, and she has the moon in the correct location, but she has it labeled as a "waning crescent phase."
Transfer Task Meets	A Priori	Transfer Task	Student thoroughly responds to each application question.	Student writes "the phases of earth would of been a waning gibbous" Student includes a detailed explanation of how he deduced this phase.
Actions of PBL Tutor	Emergent	Equitable Classroom	Opinions of PBL process by student-participants	I intervened as the tutor to encourage equal participation from all students
Science as Confusing	Emergent	Equitable Classroom	Science seems confusing; PBL alleviating confusion	"Sometimes I get really confused because you have to memorize it and think about what you have learned"
Risk Taking	Emergent	Equitable Classroom	Encouraging students to take risks in the science classroom	"You were encouraging and students seemed to feel comfortable taking risks"

Appendix K:

Permission Form

January 6th, 2017
Dear [Parent]:

My name is Ms. Caroline L. Moon. I am your child's eighth-grade science teacher. I am conducting an Action Research Study to examine the impact of Problem-Based Learning (PBL) in one classroom of eighth-grade science students. Specifically, I am attempting to find a more effective way of teaching tides and the Sun, Earth, Moon (SEM) system to my eighth-grade students. I am planning to conduct a qualitative action research study to determine the impact PBL-based curriculum on the conceptual understanding of concepts in the SEM system (phases of the moon, seasons, rotation of Earth). Your child's participation will involve completing a series of PBL scenarios and creating representations of SEM phenomenon. In addition, I am also seeking to improve scientific discussion in the classroom for all students. Your child has been selected to participate in a focus group interview with myself and several other students. The interview will take approximately 25 minutes to complete. The interview will be tape recorded, transcribed, and analyzed for this Action Research study.

If you or your child chooses not to participate, there will be no penalty. It will not affect your child's grade, treatment, services rendered, and so forth, to which you or your child may otherwise be entitled. Your child's participation is voluntary and he/she is free to withdraw from participation at any time without suffering any ramifications. The results of the research study may be published, but your child's name will not be used. Data collected will be kept confidential and will not be shared with anyone. I will destroy all data within one year of completing the study. If you have any questions concerning this study or your child's participation in this study, please feel free to contact me.

Sincerely,

Ms. Caroline L. Moon

By signing below, I give consent for my child to participate in the above-referenced study.

Parent's Name: ___________________________ Child's Name:_________________
Parent's Signature: ____