PHENOMENON-BASED INSTRUCTION IN THE ELEMENTARY CLASSROOM: IMPACT ON STUDENT ENGAGEMENT AND ACHIEVEMENT IN SCIENCE CONTENT LEARNING

by

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A dissertation

submitted in partial fulfillment

of the requirements for the degree of

Doctorate of Education in Curriculum and Instruction

Boise State University

May 2022

BOISE STATE UNIVERSITY GRADUATE COLLEGE

DEFENSE COMMITTEE AND FINAL READING APPROVALS

of the dissertation submitted by

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Dissertation Title: Phenomenon-based Instruction in the Elementary Classroom: Impact on Student Engagement and Student Achievement in Science Content Learning

Date of Final Oral Examination: 16 March 2022

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DEDICATION

I would like to dedicate my dissertation to my amazing family! First to my wife, Heidi, who with her love and patience was so supportive through the doctoral process and encouraged me to spend many hours working in the office on weekends, when I would rather be doing many other non-productive activities. To my mother, who not only is a “legend” in the community, but is and will always be a legend to her son. Mom was the “writing center” through the entire dissertation process and was willing to give constructive criticism that continued to help me reflect and improve my writing and research. To my brother, whose critical feedback on my research, encouragement and love helped to push me across “the finish line" even through the difficult times when I was stuck in the process and ready to “throw in the towel.” Thanks Bro, I couldn’t have gotten through this process without you! Finally, to my dog, Poppi, who even after so many difficult and demanding days researching and writing, she would be there with unconditional love whether to lick my face or be ready to walk in the Boise Foothills to help me clear my mind and get refocused.

ACKNOWLEDGMENTS

I was very fortunate to have such an amazing committee that continually helped me complete this journey. I especially want to thank my co-chairs, Dr. Julianne Wenner and Dr. Sara Hagenah. Both of these professors were not only amazing thinking partners through the dissertation process, but have worked collaboratively with me to help change the landscape of science education in Idaho by supporting state science standards and working with science educators around the state implementing phenomenon-based inquiry into classrooms. Thank you so much for all your support, and I know the three of us will continue to work together in the future to continue to improve science education and empower teachers to provide quality science instruction for all students. Thanks for being such great mentors and friends!

I also would like to give a special thanks to Dr. Soñia Galaviz whose support and time being the second researcher through this process was invaluable! Your work in STEM education and with students is such an inspiration to me and I hope before our careers end we have an opportunity to work together in a school!

ABSTRACT

Phenomenon-based teaching is a multidisciplinary instructional approach based on student inquiry and problem solving. Students investigate and solve their own questions by applying what topics are relevant to the problem. The goal of phenomenon-based learning is to prepare learners to solve problems in real life. Instead of passively learning abstract or disconnected concepts, phenomenon-based instruction provides student's rich and meaningful context to the subject by actively engaging them to discover knowledge and skills required to solve the problems. Phenomenon-based instruction gives students the opportunities for discourse, argumentation-using claims with supporting evidence, and making sense of the material being covered, ultimately engaging them in the subject matter. This mixed methodology study focused on how phenomenon-based instruction in elementary classrooms affect student achievement and student engagement in the subject of science.

In this study four different fifth grade classrooms with a total of 106 students participated in this controlled study. All four classrooms were provided with the same science topics during the same week. Two classrooms taught using traditional science instruction, while the other two classrooms were taught using phenomenon-based instruction.

Phase One of the study measured whether there was a change in student achievement by using two-way analysis of variance tests. The students who received phenomenon-based instruction had higher scores on both factual and conceptual components of their posttest. The analysis found a statistically significant improvement on factual knowledge of the students who received phenomenon-based instruction compared to students who received a more traditional approach of science instruction.

Phase Two of the study assessed whether the phenomenon-based instruction affected student engagement. Data was triangulated by discourse analysis of student data, statements made by students, and observations of the researcher and teachers. Students who received phenomenon-based instruction demonstrated higher levels of engagement by students asking more science-related questions, discussing more frequently using argumentation strategies, and making connections through sensemaking.

Phenomenon-based instruction positively affects both student achievement and engagement in fifth grade elementary science education. Additional research is needed to measure whether this type of instruction would have the same impact on other grades or disciplines.

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LIST OF ABBREVIATIONS

CER	Claim, Evidence, Reasoning
ELA	English Language Arts
FOSS	Full Option Science System
IRE	Initiation-Response-Evaluation
ISAT	Idaho Standards Achievement Test
ISCS	Idaho Science Content Standards
NAEP	National Assessment of Educational Progress
NCES	National Center for Educational Statistics
NGSS	Next Generation Science Standards
NRC	National Research Council
NSTA	National Science Teaching Association
PBI	Phenomenon-Based Instruction
PD	Professional Development
SSAT	State Standard Achievement Test
STC	Science and Technology for Children

CHAPTER ONE: STATEMENT OF PROBLEM

Background of the Study and Current Problem

High-quality elementary science education is essential for instilling wonder for science that lasts a lifetime, establishing a sound foundation of learning in later school grades, and in addressing the critical need for a well-informed society (National Science Teaching Association [NSTA], 2012). A major goal for teaching elementary science is to help children develop ideas based on evidence which they have personally collected and then to use these ideas to explain and predict natural events around them (Rhoton, 2018). Research points to the early elementary grades as a pivotal time for the development of science learning trajectories and achievement gaps (Curran, 2017; Curran & Kellogg, 2016; Kohlhass et al., 2010; Quinn & Cooc, 2015). However, recent studies show that elementary teachers struggle not only to find time during the school day to instruct science, but also grapple with teaching science using inquiry where students are at the center of their learning (Banilower, 2019; Morgan et al., 2016).

Elementary students who learn to think like scientists not only gain a better understanding of the concepts in their science classes but can also conceptualize the content better (Cannady et al., 2019). One way this happens is to help students to appreciate how science works by providing them opportunities to interact and discuss real-world phenomena. A phenomenon is an observable event that occurs on Earth or in the universe. In the classroom, students and teachers use scientific knowledge that is then applied to help explain or predict that phenomenon (Mancuso, 2017). As teachers guide students toward the development of knowledge and skills in science, it is necessary to engage, excite, and drive student learning, which can be completed through the use of relevant, real-world phenomena (Mancuso, 2017). Using phenomena in the classroom also increases students' engagement, motivates them to practice higher-level critical thinking skills, and promotes meaningful learning experiences (Edwards & Mercer, 2013). Research has shown that if students are truly engaged in learning science, their deeper understanding of science concepts will increase (Grabau & Ma, 2017; Parsons & Taylor, 2011). Fredricks & McColskey (2012) also showed that overall academic performance was greater for elementary students who were attentive and engaged compared to those who were not attentive and engaged.

The NSTA, the world's largest association of science educators, issued a position statement underscoring the importance of high-quality science education to the nation's elementary students (NSTA, 2014). The statement focuses on students in kindergarten through 5th grade and establishes four key principles to guide effective science learning. The first principle is that an elementary educational environment plays a key role in student learning. When a teacher considers all aspects of space (physical, socio-emotional, and intellectual) for creative and in-depth learning, a student will thrive (Devries & Zan, 2012). The second principle is elementary students should engage in scientific and engineering practices as they develop conceptual understandings over time. High-quality science instruction moves students from curiosity to interest to reasoning (Moulding et al., 2015). The third principle is that elementary students can and should engage in science within the broader community of science. When a student can tap into a scientific community, like peers in a classroom, it allows them to become an active participant within diverse cultures while practicing skills like scientists (NSTA, 2012). The final principle is that there must be adequate time in every school day to engage elementary students in high-quality science instruction that actively involves them in the processes of science.

Another contribution to support the elementary science education community was the development and implementation of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). The NGSS states the goal of science education is to construct explanations for the cause of phenomena. Since science phenomena is present in every child's daily life, science education aims to promote not only an understanding of science knowledge, but also scientific literacy and responsible citizenship (Abell et al., 2013). This updated emphasis in science education, exemplifies that elementary students need more opportunities to observe phenomena, engage in problem solving, and provide explanations of their thinking (Katz, 2010).

Even with the clear directions from the NSTA and NGSS, teachers in many schools still struggle with teaching elementary science. Currently, two major challenges face elementary teachers with science instruction. First, they currently do not dedicate enough time in the school day to teach science (McClure et al., 2017). Science receives far less instructional time than other core subjects (Banilower, 2019). The second challenge is elementary teachers need more specialized training in the science curriculum (Curran & Kitchin, 2019). They are often generalists, teaching many different subjects during the day and do not always have the proper training or expertise in the science content to make it meaningful and relevant to students (Banilower, 2019; Blank, 2013). Because of this, teachers end up using more traditional science teaching methods, i.e, presenting facts while students listen and conducting step-by-step procedural labs that textbooks have laid out in the teacher's edition. These traditional methods have been researched extensively with little measurable effect on student achievement or engagement (Appleton & Kindt, 2002; Ireland et al. 2014; NRC, 2000).

Since student achievement and engagement in science was not showing improvement, the NRC published *Taking Science to School: Learning and Teaching Science in Grades K-8,* a comprehensive report that helped spark the debate about what the purpose of science is for a child and how they learn in science (NRC, 2007). Some of the poignant questions discussed were:

1. When do children begin to learn about science?
2. How can science education capitalize on children's natural curiosity?
3. What are the best tasks for books, lectures, and hands-on learning?
4. How can teachers help promote more student discourse in science?

This report promoted school districts, administrators, and teachers for the last decade to try to answer these questions through different instructional methods and modifications to curriculum.

As educators continue to strive to find inventive solutions to overcome the elementary science challenges, one approach has emerged that deviates from traditional science routine methods of instruction and instead infuses research-based innovative ideas into their current standard practices to teach science (Noddings, 2005; Symeonidis & Schwarz, 2016). This idea is phenomenon-based instruction. Phenomenon-based instruction is designed to give students time and space to structure their own guiding questions as a way to encourage their investment in learning and engagement in reasoning (Metz, 2011). Phenomena-based instruction also builds on students' embodied knowledge and understanding of the world while confronting their misconceptions (NRC, 2009). Phenomenon-based strategies integrate English language art skills, like speaking and listening, by involving students in scientific discourse to help make and communicate evidence-based conclusions and decisions (Moulding et al., 2015). To tackle time constraints, elementary teachers use strategies that maximize learning opportunities for their students. To date, research is limited on whether implementing phenomenon-based instructional strategies in science instruction at the elementary level is effective. This study provides an in-depth analysis through the lens of social-constructivism to detail the impact of phenomenon-based instruction on both student achievement and student engagement in elementary science classrooms.

Research Questions

The research questions for this study are:

1. How does phenomenon-based instruction affect student achievement in elementary science?

2. How does phenomenon-based instruction affect student engagement in elementary science?

Significance of the Study

The benefits of this study are two-fold. First, by understanding whether phenomena-based instructional practices are effective or not in an elementary classroom setting, teachers, schools, and even districts could re-evaluate their current approaches to the instruction of science. Second, the data gathered can contribute to the discussion of elementary science education reform. The goal in any educational setting is to provide the best instruction to students. Comparing and contrasting the traditional instructional approach to phenomena-based instruction could transform elementary science education.

Organization of the Study

The study is organized into five chapters. The current chapter serves to provide an overview of the study. The second chapter examines the current state of traditional science instruction and introduces the components of phenomenon-based instruction. In addition, science achievement and engagement is defined and measured. Chapter three will explain the mixed methods approach by using data from both quantitative and qualitative metrics. Chapter four provides the findings of data collected from both the quantitative and qualitative metrics results and the effect phenomenon-based instruction has on both student achievement and engagement in elementary science. The study concludes with a discussion of the findings and recommendations for future research and ideas for implementation of phenomena-based instruction.

CHAPTER TWO: LITERATURE REVIEW

Introduction

Through the lens of social-constructivism theory (Vygotsky, 1978) this review of literature aims to compare the components and effectiveness of current elementary science instructional practices to phenomenon-based instructional practices. First, a clear background of traditional elementary science practices will be explained followed by definitions, components, and examples of phenomenon-based learning. Next, three distinct pedagogical outcomes of phenomenon-based instruction; student discourse, argumentation and sensemaking, will be discussed in detail while providing current research on each component and the specific implications of how each component affects student understanding of science concepts. Finally, research on student achievement and engagement will be provided to help make a connection with the research questions and phenomenon-based instruction.

Elementary Science Instruction

The increasing importance of science has created pressing educational demands. Science is not just a subject that should be taught in elementary school, but a way of helping students understand the world. It has become essential for anyone who wishes to be considered literate to have a basic understanding of the world in which they live (Kelana, 2018). Science is about continually acquiring new knowledge by observing and asking questions about phenomena while keeping an open and curious mind (Mancuso, 2017). Over the last 50 years, the concept of science literacy has become the term used to describe a goal of science education (Roberts & Bybee, 2014). Science literacy can be defined as the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in cultural and civic engagement, and economic productivity (NRC, 2012). Millar and Osborne (1999) reviewed the purpose of science in education and felt that many schools' science instruction focus was on a small specific population of students, for example gifted and talented students and high achievers, instead of being directed to all students. Their recommendation was that science literacy is necessary for all young children growing up in our society to enable them to make informed judgements regarding social and ethical issues relating to science. Science literacy can be understood as a tool that "will help students personally solve meaningful problems in their lives, shape their behavior, and inform their most significant practical and political decisions" (Feinstein, 2011, p. 169). Given the importance of science literacy, making science relevant and teaching science in elementary school is crucial for students to build a foundation of science understanding (Cervetti et al., 2012).

Policymakers contend that improving K-12 science and mathematics education is one of the most pressing issues in building the intellectual and economic foundations needed to ensure the nation's security and standard of living (NRC, 2009). While trying to promote scientific thinking and develop more science literacy among students, the average time students spend learning science is well below the time students learn other subjects (Judson, 2013). The Horizon Research study showed that elementary science instruction takes a back seat to reading and math and receives little time in a school day (Banilower, 2019). Elementary classrooms spend less than 2.5 hours per week teaching science, compared to the time spent teaching English Language Arts (ELA) which is over 11.5 hours a week and mathematics which is at 5.4 hours a week. Only one quarter of the elementary classrooms surveyed had a primary goal of students learning *how to do* science. Instead, over 80% of the time, teachers use lecture and whole class discussion practices when teaching science. In other words, with instructional time for science being limited, teachers reported putting an emphasis on presenting concepts, but focused significantly less on having students learn how to do and understand science or encouraging an interest in science. The results of the time spent during the day for elementary science is troubling given research that indicates students who ultimately decide to continue to take more advanced science classes in high school and go into the high demand of science, technology, engineering and math (STEM) fields make their choices as early as upper elementary school (Blank, 2013). If students are not given many opportunities to learn science in elementary school (Banilower, 2019), students will likely not pursue STEM careers. Despite all these concerns about science literacy and student achievement in STEM fields, the time spent on science education remains relatively low in elementary schools.

There are three main reasons why science is not taught more frequently in elementary schools: (a) having a narrowed curriculum; (b) teachers lacking adequate content knowledge and pedagogical practices in science; and (c) teaching inquiry science is challenging and takes time to plan effectively. Each of these alone inhibit science from being taught, but a combination of all three can be detrimental to student achievement.

Narrowed Curriculum

A narrowed curriculum, which is commonly typified as concentrating instructional time on reading and mathematics, takes away time spent on teaching science (Rosenshine, 2015). One rationale of this narrowing of curriculum is because student achievement results from reading and mathematics are always included in states' accountability standards (Judson, 2013). To make matters worse, in schools that have been targeted for improvement due to low student achievement on standardized tests, little or no time is spent on teaching science (Olson, 2009). However, examination of National Assessment of Educational Progress (NAEP) data has shown that states who integrate science into other standards, such as ELA and math, achieve significantly higher fourth-grade student achievement in science while also maintaining equivalent achievement in mathematics and reading (Hirsch, 2019; Judson, 2013). In other words, schools can still maintain high test scores while integrating science into their daily curriculum, making narrowing the curriculum an unnecessary and unfortunate strategy for schools.

Inadequate Training and Knowledge by the Teacher

Another reason science instruction is taught minimally in elementary schools is because many elementary teachers lack adequate science background to teach science accurately (Nowicki et al., 2013). Elementary teachers face increasing demands to engage their students in the science processes and argumentation while also preparing them with the knowledge of science facts, vocabulary, and concepts. Most elementary teachers are educated as generalists and are required to teach multiple subjects during the school day. Within science, there is so much content and teachers need to have enough background in earth, physical and life sciences to help guide authentic experiences for students. Teachers also have to help students construct their own understanding of natural phenomena while fielding students' questions and correcting misconceptions (NRC, 2000). Many elementary teachers have limited background in science, usually taking only one science methods course in their preservice classes, and are often intimidated to teach science (Davis et al., 2006; Windschitl et al., 2012). In national polls, elementary teachers indicate that they are not scientifically literate and feel less qualified to teach science compared to all the other academic subjects, in terms of both content and subject-specific pedagogy (Banilower, 2019; Weiss et al., 2003). Because of the lack of confidence and schooling in science, many elementary teachers emphasize students learning basic science concepts and less than half of the teachers emphasize students learning the science process and inquiry skills (Banilower, 2019).

Lack of Time and Motivation to Plan Appropriately

A final reason that science instruction is minimal in elementary schools is that preparing and teaching a science lesson not only takes time, but also requires using an inquiry pedagogy that elementary teachers are less familiar with. Inquiry science provides an ideal framework for helping students develop strong skills in problem solving and critical thinking while learning a broad knowledge of the science content (Varelas et al., 2008). The inquiry approach to teaching science is where students are actively involved in scientific investigations that provide them opportunities to explore possible solutions, explain phenomena, elaborate on student-driven questions, and evaluate findings (Harris & Rooks, 2010; Gillies & Nichols, 2015). But teaching inquiry science in the elementary classroom is a challenging task. Elementary teachers must engage students in scientific exploration that is genuine and relevant. Depending on the science lesson, they must be prepared to guide students to generate questions, design experiments, plan procedures, carry out investigations, report their findings, analyze results and draw conclusions to create scientific explanations by constructing and evaluating arguments based on evidence (Zembal-Saul, 2009; Minner et al., 2010). Teaching science in an inquiry manner is a highly complex task that requires a high level of planning and preparation as well as having pedagogical and science content knowledge (Newton & Newton, 2001). Teachers must also make decisions based on knowledge of how children learn, how learners are likely to think, and what specific content or science processes they will find confusing. Children should have the opportunity to participate in the full range of science education activities, including direct instruction, demonstration, and inquiry activities (Hayes & Trexler, 2016). Yet evidence suggests that inquiry and the opportunity for inquiry provided by hands-on, lab based activities are neglected in many elementary classrooms (Banilower, 2019; Capps & Crawford, 2013).

Summary

All three of these factors could lead to some of the reasons that elementary teachers either abandon teaching science in the classroom or use traditional programs to teach science. Nonetheless, there are methods to support high-quality science learning for all students.

Traditional-based Science Instruction

The direct or traditional method of teaching science has been a standard model for the past century in elementary education. In this model, the teacher is the source of information, and is responsible for addressing all the content of a specific lesson, while the students listen and respond. The teacher has the responsibility to keep the student's attention and convey the main learning points of the lesson and present science through textbooks and lectures as a static body of knowledge (Lee, 2020). A traditional science lesson starts with the objective for the lesson being presented by the teacher. Next the teacher presents the science vocabulary and content pertinent to help students understand the objective. The students then engage in an activity to help reinforce the science content with a step by step set of procedures usually created by the textbook company. The students follow these directions and complete a worksheet with questions that may include matching science definitions with appropriate vocabulary, explaining what happened in each step of the activity, or regurgitating facts learned from the teacher or reading the textbook (Mancuso, 2017). Through this process students do, indeed, learn scientific information, but science may not always make sense (Capps & Crawford, 2013).

For much of the 20th century, elementary schools used textbooks to teach science, when science was taught at all (Klahr & Nigam, 2004). Over the last few decades, science instruction has started to be more guided by hands-on activities (Chin & Brown, 2000; Cuevas et al., 2005; Minner et al., 2010; Schroeder et al., 2007). Hands-on science typically engages students in research activities in the classroom. Many school districts have adopted complete curricula of hands-on activities to effectively replace the use of science textbooks in elementary classrooms. Some examples are: Full Option Science System (FOSS; Delta Education), developed at the Lawrence Hall for Science (at the University of California, Berkeley), Science and Technology for Children (STC; Carolina Biological Supply Company), developed by the National Science Resources Center (a joint enterprise of the National Academy of Sciences and the Smithsonian Institution), and Insights (Kendall/Hunt). Other curricula offer a combination of textbook and hands-on activities (e.g. Scott Foresman Science). The hands-on activities provide students with opportunities to engage in exploration and sense making with the science content.

Even though these new hands-on programs were entertaining and had the student learners more engaged, they were once again not made applicable to the real world (Moscovici & Nelson, 1998). Educational research has shown that both the traditional programs with lectures (i.e., presenting facts while students listen) and traditional hands-on cookbook labs (which are defined as labs that contain explicit instructions in a step-by-step procedure that choreograph each action taken by the learner; e.g., “do this,” “measure that,” “record this,” “come to this answer,”.) found in many programs are not the most effective ways for students to learn and to retain what they are taught (Symeonidis & Schwarz, 2016). Because these methods are not effective a new form of science instruction has been introduced; phenomena-based instruction (NGSS Lead States, 2013; NRC, 2012).

Researchers on elementary science reform emphasize the need for students to engage in scientific inquiry while communicating like scientists (Harlen & Qualter, 2018). Engaging students in inquiry can provide a powerful learning experience where students not only learn about science content but also gain reasoning and critical thinking skills. Students come to understand the nature of scientific problem solving as the pursuit of meaningful questions through the use of procedures that are thoughtfully generated and evaluated (Krajcik et al., 2014).

Theoretical Framework in Phenomenon-based Science Learning

Phenomenon-based learning is a new term in the field of elementary science instruction and was recently popularized in Finland in 2016 (Finnish National Board of Education, 2016; Lonka et al., 2018). This method centers on the student understanding a phenomenon – an observable event – while using various methods and perspectives that overlap to make sense of this phenomenon (Wakil et al., 2019).

Phenomenon-based teaching is rooted in constructivism (Piaget, 1969). The theory of constructivism, in which the learners are seen as active knowledge builders as they attempt to make sense of their experiences (Piaget, 1969), ties directly to elementary students learning through relevant phenomena. Constructivism views learning as the learners' building new knowledge based on their past experiences and prior knowledge (Bruner, 1990; Ciampa, 2012). Students' interpretations and experiences shape what they know of the world and that humans create knowledge and meaning rather than acquiring it (Ertmer and Newby, 2013).

Any experience that a student has with an idea becomes part of the meaning that they assign to it, so different students make different meanings of the same idea (Duffy & Jobassen, 1992). In an elementary classroom setting, exemplary teachers provoke constructive mental processes in their students so that they can respond to situational demands of the task and make sense of the environment as they encounter it (Dewey, 1938; Duffy & Jobassen, 1992). Teachers need to keep in mind that students build upon previously acquired knowledge which results in deep learning and helps to eradicate the problem of forgetting (Noddings, 2005).

Phenomenon-based learning also has its roots in Vygotsky's social constructivism learning theory. The key guiding principles of Vygotsky's interpretation of social constructivism is that knowledge is constructed by learners, knowledge is experientially based, learning is social, and all aspects of the student are connected (Kapur, 2018). Vygotsky defined learning as co-constructing the meaning of both content and practices, which occurs through the support of others in the classroom, such as teachers and other students (Vygotsky, 1978). Vygotsky's theory also stresses the fundamental role of social interaction in the development of cognition, as he believed strongly that community plays a central role in the process of making meaning (Vygotsky, 1978). The traditional model of education is where the teacher transmits information and students act as receptacles (Halm, 2015), whereas, Vygotsky's theory maintains the need for active learning, creating a classroom environment in which the teacher and students act as collaborators to facilitate meaning construction that creates learning (Vygotsky, 1978). Collectively these theories propose that learning is best achieved by students who actively construct their own experiences and by having students socially construct their knowledge in groups while asking questions.

From these theories, a few specific components align when using phenomena in the classroom. These components are: (a) actively constructing knowledge while building background; (b) providing meaningful learning in a collaborative setting; and (c) providing relevant, real-world applications. These three components are described in more detail below.

Constructing Knowledge while Building Background

Centering elementary science education in authentic phenomena allows learners to be seen as active knowledge builders while information is being constructed as a result of problem solving (Silander, 2015). Elements of inquiry learning (Van Uum et al., 2017) and problem-based learning (Kilroy, 2004) are embedded in phenomenon-based instruction and help students construct meaning while building on their prior knowledge. Using phenomena can help develop a level playing field because all students are building background knowledge on a specific event by asking questions and discussing as a group.

Meaningful Learning in Collaborative Settings

Using phenomenon-based instructional strategies allows learning to occur in a collaborative setting which supports students making sense of their experiences (Taber, 2012). Meaningful learning is considered a personal process in which students make meaning of what they see and hear in their surroundings (Kim, 2001). Every student in a classroom brings unique backgrounds and cognitive resources, which lead to the construction of personal knowledge for all students when given the opportunity to learn through social interactions.

Building Context Using Relevant Applications

Explaining phenomena allows students to build general science ideas in the context of their application, and to better understand the real world, leading to deeper and more transferable knowledge (Silander, 2015). Phenomenon-based approaches allow students to identify and have an answer to “Why do I need to learn this?” before they even know what the “this” is. In contrast, in a traditional classroom, students might not understand the importance of learning science ideas that the teacher presents, if they are unconnected from phenomena. This helps classrooms move away from having students just memorize facts that will soon be forgotten, and allows students to do real science while being engaged in collaboration, communication, and critical thinking (Chesnutt et al., 2018).

Summary

It becomes clear that phenomenon-based instructional strategies are grounded in a constructivist and social constructivist epistemology. Authentic problem solving, inquiry learning, learning with others, developing multiple perspectives, and incorporating real-world applications are some of the components related to social constructivism (Kim, 2001). These approaches imply that learning is mediated and controlled by the learner, who is an active participant and constructs knowledge while working with others (Symeonidis & Schwarz, 2016).

Characteristics of Phenomenon-based Science Instruction

Phenomenon-based instruction is a learner-centered, multidisciplinary instructional approach that is based on student inquiry and problem solving. There are five primary characteristics of phenomenon-based learning (Symeonidis & Schwarz, 2016):

1. *Real world application*: The real world is the foundation of phenomenon-based learning. This is always the starting point and is repeated at every stage (NSTA, 2014). Students and teachers choose to focus on real-world phenomena; such as why a rubber ducky floats in a bathtub and a doll doesn't or why a toy car moves farther when pushed on the gym floor compared to a carpeted floor. Students study a phenomenon that

interests them, and use scientific inquiry and problem-solving skills with the aim of understanding it and demystifying it (Silander, 2015).

2. *Question and more questions:* Phenomenon-based learning thrives on curiosity, and so students are encouraged to question what is around them (Bendici, 2019; Mancuso, 2017). This is very similar to the Socratic Method. The Socratic Method incorporates other preferred methods of instruction such as the case method, lecture, and small groups (Plato & Saunders, 1987). The Socratic Method as defined by the *American Heritage Dictionary of English Language* is:

> a pedagogical technique in which a teacher does not give information directly but instead asks a series of questions, with the result that the student comes either to the desired knowledge by answering the questions or to a deeper awareness of the limits of knowledge (American Heritage Dictionary, n.d).

Through this dialogue the teacher questions and guides students in order to discover answers. Phenomenal based learning echoes this approach, prioritizing *how* over *why* in order to inspire students to make observations and question (Inouye et al., 2020).

3. *Contextualization:* Phenomenon-based learning builds tangible connections between curriculum theory and the real world, but it also serves to link the various, separate subjects that students learn in schools (Chin & Brown, 2000; Odden & Russ, 2019). For example, the study of fossils and sedimentary layers around a region is a perfect mix of studying geography and science, which has helped scientists come to a clearer understanding of Earth's biodiversity millions of years ago while relating to it today.

Phenomenon-based teaching creates more opportunities for integrating different subjects and themes to real world phenomena. The phenomena are studied as complete entities, in their real context, and the information and skills related to them are studied by crossing boundaries between science subjects. Real-world phenomena provide the starting point for learning. Phenomenon-based instruction starts from the shared observation of the genuine, real-world phenomena to a whole class discussion (Roth, 2014).

4. *Change in a teacher's role*: Phenomenon-based learning recasts the teacher's role, changing them from a provider of knowledge to a guide who helps students find knowledge on their own (Ireland et al., 2014; Waterson, 2009). This is contrary to many pedagogical practices found in elementary education, especially when teaching from a traditional-based approach.
5. *Utility of information*. Learners see a utilitarian value in the theories and information in the learning situation (Lähdemäki, 2018). The theoretical ideas learned are anchored in practical situations and phenomena that the learner can better understand and see the usefulness of learning the information (Mancuso, 2017).

Differences between Traditional Approach and Phenomenon-based Approach

There is a clear difference between the traditional and phenomenon-based approach to instruction in elementary science. In a traditional approach, the lesson is centered on a particular objective which is articulated to the students at the beginning of the lesson. While in phenomenon-based instruction, the lesson begins with presenting a phenomenon to students which could be either an image, a demonstration, or a short video clip of a real-world event that directly ties to the lesson's learning target. Next, the traditional teacher usually lectures about the topic while explaining to the whole class the specific scientific vocabulary and concepts they need to know. The traditional teacher will then assign students a reading from the textbook or a cookbook lab to explore to build on their understanding of the science concepts taught during the lecture. In phenomenon-based instruction, after students have time to ask questions and wonder about the phenomenon, they are provided an exploratory activity before any content or vocabulary is given by the teacher. During this exploration, students are constructing their own knowledge while discussing, observing and asking more questions. The teacher's role, instead of giving all the science information, is to guide and listen to student conversations while pressing students to connect their ideas back to the original phenomenon. Finally, at the end of a typical traditional lesson, an assessment on science vocabulary is administered. This type of assessment does not show if students have a comprehensive understanding of the scientific information or how it applies in the real-world, but instead is a regurgitation of the information taught (Lee, 2020). In phenomena-based instruction, the assessment given connects back to the original phenomena or applies to other related events. Thus, the entire science lesson is dedicated to developing students' ability to explain the "how" and "why" of real-world applications. Table 2.1 summarizes the comparison of traditional and phenomenon-based instruction.

Table 2.1. Comparison of Traditional vs. Phenomenon-based Instruction

Traditional	Phenomenon-based
• Lesson starts by telling students what they will be learning in the lesson • Teacher lectures and provides definitions to key vocabulary • Teacher assigns activities from resources like textbook, cookbook labs, videos • Assessment focuses on defining vocabulary	• Lesson starts showing a phenomenon while allowing students to wonder and ask questions • Students explore through an activity before content is taught • Explanation of the content is tied back to the activity and phenomenon. • Assessment focuses on sensemaking

Using Phenomenon-based Instruction in Elementary Science

Using phenomena has traditionally been a missing piece in elementary science education, which too often focuses on teaching general concepts and ideas that students have either not experienced or applied to real world contexts (Banilower, 2019; Chesnutt et al., 2018). Numerous studies have argued for the innate ability of children to wonder about natural phenomena they encounter and how these experiences can offer interest in the sciences (Chesnutt et al., 2018; Milne, 2010). It is undeniable that many elementary students are curious by nature and this curiosity drives emotion and a pursuit of understanding (Yager et al., 2012). Scientists like Albert Einstein have linked science, curiosity and wonder:

> The most beautiful thing we can experience is the mysterious. It is a source of all true art and science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed. (Einstein, 1931, pg.6)

These words from Einstein exemplify how scientific phenomena feed moments of awe and inspiration and how wonder exists at the heart of science inquiry and phenomenon-based teaching. It is the wonder of a phenomenon that drives the desire for students to be engaged to learn more, gives them the courage to collaborate together, and supports them in working toward a deeper understanding of the world.

There are different structures inherent to using phenomenon-based instruction strategies in the elementary classroom. Phenomenon-based learning usually starts with either an observation of a phenomenon or a relevant problem posed by the teacher. The students next build questions and answers together through discussion using their background knowledge and prior experiences to guide them (Silander, 2015). The student proposed questions direct them to either an exploratory activity or research to help them find solutions or answers to their questions. During this learning process, students are developing hypotheses and working theories while taking part in their own knowledge creation through scientific practices in an effort to increase understanding (Inouye et al., 2020). During this structure, teachers facilitate the process by guiding students to learn concepts and skills needed to answer questions and solve the problem initiated by the phenomenon. Finally, students communicate and deliver their ideas and solutions in a relevant format that demonstrates a better understanding of the science concepts being addressed.

Outcomes of Phenomenon-based Instruction

There are three outcomes that should be present in the elementary classroom when teachers use phenomenon-based instructional strategies. They are student discourse, argumentation, and building explanations through sense making (Odden &

Russ, 2019; Symeonidis & Schwartz, 2016; Zembal-Saul, 2009) (See Figure 1). Each of these components are discussed in more detail and how they are impacted by using phenomenon-based instruction in the science classroom.

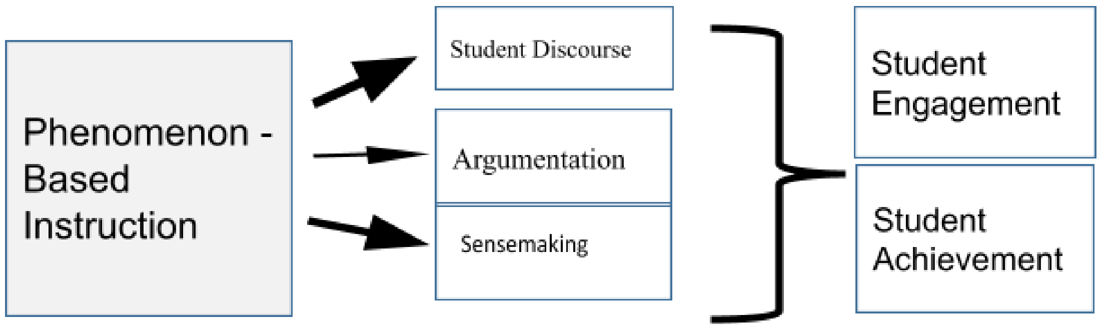

Figure 1. Phenomenon-Based Instruction

Student Discourse

The call to engage students in discourse or talking productively on the topic in an academic environment is at the heart of science education reforms as students are expected to participate in disciplinary discourse at more rigorous levels than ever before (Siayah et al., 2019). These aspirations, however, contrast what is typically seen in elementary science classrooms today (Colley & Windschitl, 2016). Traditionally, whole-class discussions are times when teachers simply explain science ideas to students instead of having students take a more central role in discourse work like developing models, creating explanations, and arguing with evidence (Corcoran & Gerry, 2011; Davis & Krajcik, 2005). Others note that encouragement to talk about their learning not only generates excitement and engagement about the topic but increases learning (Peterson & Eeds, 1990). Unfortunately, this kind of talk that develops deep understanding is rarely offered in elementary schools (Queenan, 2011). Studies of teacher talk suggest that as much as 70% to 80 % of instructional minutes are filled with the voice of the teacher

(Strum & Nelson, 1997). This is regrettable because it has long been known that students can serve as coaches in the zone of proximal development where students perform at higher levels with the assistance of others (Vygotsky, 1962). It is also difficult for students to build on existing concepts if they are given little opportunity to engage in active practice and discussion (Lemke, 1990). Stated simply, a student cannot develop the ability to explain, to elaborate, to argue or even to question without an opportunity to practice these skills with others through academic discourse (Fisher et al., 2020).

Despite the fundamental role classroom discourse plays in many approaches to learning, it is recognizably difficult to manage in an elementary classroom (Anderson et al., 2007). Teachers often struggle in managing rich discourse in tandem with equally rich inquiry, so they often fall back on more traditional approaches. One traditional practice to get students talking in classrooms is the Initiation-Response-Evaluation (IRE) sequence (Mehan, 1978). In IRE, a teacher asks a question to the whole class, waits for a particular student's response and then evaluates that response. This style of discussion is an effective way for checking factual knowledge, but does not produce many benefits with regards to higher order thinking (Lave & Wenger, 1991).

Instead the IRE model is a verbal test with only one right answer. Further, this kind of discussion is not intended to help students build on their beginning knowledge, but simply functions to test what they already understand (Herrenkohl & Guerra, 1998). Even if a higher order question is posed by the teacher, only one student is able to answer before the teacher evaluates the answer and ends any form of discussion. Using phenomenon-based instructional strategies helps elementary teachers move away from using the traditional IRE model and in turn provides students opportunities to guide discourse by allowing them to generate and ask their own questions.

Phenomenon-based instruction contributes to more student discussion by asking questions about the phenomena, which also increases student engagement (Antonetti & Garver, 2015). Great thinkers of the past century in education such as Dewey, Vygotsky, and Bruner, all advocated for dialogue where students are actively involved in constructing meaning (Symeonidis & Schwarz, 2016). Learning is constructed socially before being internalized (Vygotsky, 1978). However, in relation to science, classroom discourse is often focused on just the use of scientific language and vocabulary during a class discussion or lesson (Anderson et al., 2007). Using phenomenon is a way to make meaningful talk a core activity in the science classroom. After introducing the phenomenon, students are asked to explore and interact with the phenomenon and then discuss it with their peers to figure out what is happening and develop questions of wonder. During this process, the teacher's role is not about explaining scientific vocabulary but to monitor student conversations, ask follow-up questions, and to discuss ways students could go about answering their individual questions about the phenomenon. The goal is not to simply give the students the answer of what is happening in the phenomenon, but allow a process of exploration and discovery through discourse which is a hallmark of phenomenon and the essence of science in general (NGSS, 2013). This deep learning by students is often impossible without student talk and high-quality student talk is not likely to happen in classrooms without well-designed experiences that promote meaningful understanding through a relevant exploration like a phenomenon (Fisher et al., 2020).

Three ways phenomenon-based instruction strategies support student discourse are: (a) allowing students to ask and answer their own “why” questions; (b) having students share their ideas in small group discussions; and (c) providing students’ opportunities to explore their ideas with relevant science investigations. All three of these outcomes help students to develop inferences that can be brought to discussions, increase student engagement by piquing curiosity, and give students a voice to help clarify their confusions by working with their peers (Queenan, 2011). Providing discourse opportunities in the classroom can help teachers move away from the teacher as the center of the learning process and instead move it towards students driving the learning.

Argumentation

Interest in students’ argumentation in science has blossomed in education over the last two decades (Duschl, 2008); in particular, the NGSS (NGSS Lead States, 2013) has led to this interest (Barreto-Espino et al., 2014). Argumentation is a form of communication that is integral to learning the nature of science. Argumentation is defined as the process of justification by which evidence and reasoning is used to support or explain a scientific claim (Berland & Reiser, 2009). In the real world, scientists spend a great deal of time assessing, critiquing, and defending the evidence that they use to support or challenge a claim (Zembal-Saul, 2009). Incorporating scientific argumentation in the classroom is important because we want students to participate in practices like scientists. New ideas developed by students must be shared, evaluated, and refined by the community in the classroom before it can become part of the body of knowledge that is used to explain how things work (Erduran et al., 2004). This complex practice of argumentation helps students articulate their individual reasoning, explore ideas and perspectives of other students, and refine a shared understanding of scientific ideas (Barreto-Espino et al., 2014).

The emphasis on using inquiry in science classrooms reflects a shift from science as exploration and experiment to science as argument and explanation (NRC, 2000). The NRC also asserted that argumentation should comprise a fundamental role in the science classroom: “The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it.” (National Center for Educational Statistics [NCES], 2021, p. 52). Many elementary students have not had the opportunity to experience scientific argumentation in the classroom because this practice is not used frequently by teachers. A recent study found that students who lack the ability to make scientific arguments in class usually have a lower ability to think scientifically on problems presented (Probosari et al., 2017). Therefore, a higher priority needs to be given to the development and implementation of scientific argumentation in schools. This movement to implement argumentation practices in the classroom focuses heavily on the social constructivist perspectives (Lave & Wenger, 1991; Vygotsky, 1978), which have students learning in a community that is guided by the use of a phenomenon and discourse that include central tenets of argumentation like developing claims with evidence.

Studies suggest that learning to teach elementary science through argumentation requires shifting discourse practices in the classroom so that students not only share their thinking, but also engage with each other's ideas productively with accountability (Avraamidou & Zembal-Saul, 2010; Evagorou & Dillon, 2011). To assist teachers with this shift, Zembal-Saul (2009) created an argumentation framework for teachers to use in their classroom. The KLEWS framework (which is illustrated in Table 2.2) helps students develop a structure to guide class discussion, reason publicly about the development of their claims based on evidence, and engage students authentically with the language of science (Hershberger & Zembal-Saul, 2015). By using phenomenon-based instructional strategies, students are provided this opportunity to communicate and constructively analyze arguments while developing skills and understanding of scientific concepts as explained by Zembal-Saul's framework. Engaging in argumentation through a phenomenon also helps highlight to students that science is an evolving body of knowledge based on the assessment of evidence, rather than a fixed set of facts to be memorized (Jimenez-Aleixandre & Erduran, 2007). Therefore, students who are actively involved in using argumentation in the classroom apply new understanding and skills that help them explain the initial phenomena observed.

Table 2.2. KLEWS Argumentation Framework

K	**L**	**E**	**W**	**S**
What do we think we know?	What are we learning**?**	What is our evidence?	What do we still wonder about?	What scientific principles/ vocabulary help explain?

While argumentation has been singled out as an important discourse component in science learning, elementary teachers still struggle to incorporate 'accountable talk' to promote productive student discourse that includes argumentation (Ghousseni et al., 2015; Michaels et al., 2008). Accountable talk highlights specific teacher moves to promote students talking to and with each other, rather than simply to and through the teacher (Michaels et al., 2008). A crucial move is teachers pressing students to elaborate on and justify their reasoning. Justification, especially justifying claims-evidence relations, is an important part of argumentation (McNeil et al., 2006). When teachers prompt students to justify their thinking their argumentation improves (Larrain et al., 2018; Ryu & Sandoval, 2012). Phenomenon-based instruction can support elementary teachers using accountable talk as an augmentation strategy in their classrooms. Studies have found that students need practice in using evidence in arguments to make sense of phenomenon and then articulate those understandings in academic discourse (Berland & Reiser, 2009; Lehrer & Schauble, 2007). By implementing phenomenon-based instruction, students will use the data, evidence, and science concepts to construct explanations and claims about the phenomenon under study and engage in the scientific discourse of proposing and arguing about ideas that are grounded in the phenomena presented. Phenomenon-based instruction drives the class to present claims, defend their own claims, and rebut the claims of others that they disagree with while using evidence (Driver et al., 2000). Lehrer and Schauble (2007) summarized that science must be examined, not only in terms of a product - such as students' understanding of scientific accurate explanations - but also in terms of the ways students talk and argue about phenomena within a community of practice.

Sensemaking

Science is fundamentally about making sense of the natural world. In recent years, science education researchers have increasingly studied the ways in which students “make sense” of science (Odden & Russ, 2019). Sensemaking is defined as a dynamic process of building or revising an explanation in order to “figure something out” (Tannen, 1993) and to resolve a gap or inconsistency in knowledge (Odden & Russ, 2019). Sensemaking is a form of reasoning that requires students to act on ideas generated from both academic sources and from one's own base of knowledge and experience. Three reasons why researchers believe sensemaking needs to be a part of elementary science classrooms are: (a) sensemaking promotes student engagement and "deep" learning which allows students to actively build connections between new and existing knowledge while encouraging interest in the topic (Chin & Brown, 2000; Danielak et al., 2014); (b) making sense of ideas facilitates the process of transferring ideas to new and different topics and circumstances (Kapon, 2017; Ruibal-Villasenor et al., 2007); (c) sensemaking is the way scientists and engineers construct knowledge so promoting it into classrooms can help students think "like scientists" (Danielak et al., 2014; Ford, 2012).

Sensemaking is a conceptual process in which a learner engages with the phenomena, wonders and asks questions about it, and then develops, tests, and refines their ideas to make meaning (NCES, 2021). Sensemaking in the elementary classroom is essentially the process of brainstorming possible ideas and questions related to a phenomenon. The way the process works is first students share related ideas and beliefs through discourse and then connect them together into a chain of ideas. As the chain is assembled, students check that the ideas are consistent by being involved in exploration and explanation activities (Bybee & Van Scotter, 2007). By the end of the process, if the students' sensemaking is successful, they end up with a coherent explanation that fills in the gap of knowledge and ideas truly start to "make sense." Teaching sensemaking is an effective way to use students' ideas, questions, and everyday phenomena to fuel sense-making conversations (Colley & Windschitl, 2016). By starting a lesson with a phenomenon, students are engaged in collaborative sensemaking to obtain a deeper understanding of scientific knowledge while investigating a real-world application.

Phenomenon-based instruction promotes sensemaking in the classroom. Using phenomenon-based instructional strategies helps students frame their thinking as they build a new explanation for something unknown or not fully understood by using their ideas, intuitions, and experiences (Kapon, 2017). Phenomena allow students to be involved in sensemaking by answering the questions “What?” “Why?” and “How is this happening?” In traditional classrooms, students approach learning through memorizing, reproducing scientifically correct pieces of information, or just trying to look for the right answer through the quickest and easiest method they can find (Rosenberg et al., 2006). Silander (2015) argues that to help students make sense of scientific concepts, teachers should use phenomena to help initiate and engage student learning, provided that the phenomena are rooted in real context, and that the information and skills related to the phenomena are studied across different subject areas. Because sensemaking is based on prior knowledge, using phenomena motivates students and helps fit new learning into students' existing knowledge (Bybee & Van Scotter, 2007). Sensemaking is also an integral part of the process for learning science through building and defending arguments through discourse, the two other components of phenomenon-based instruction. This encompasses the way students make claims, construct explanations, and articulate their ideas (Berland & Reiser, 2009). Students begin by interacting with one another to make sense of others’ ideas to help them build their own clear and comprehensible explanations. In conclusion, phenomenon-based instruction helps to develop discourse, argumentation, and sensemaking by enabling students to acknowledge, evaluate, and incorporate diverse student perspectives while building an explanation of the relevant phenomena being presented (Symeonidis & Schwarz, 2016).

Elementary Science Student Achievement

Students achieve when they acquire knowledge, skills, and attitudes that will prepare them not only to advance to the next grade level, but to prepare them to lead happy and successful lives (Curran & Kitchin, 2019). The most common indicator of achievement generally refers to a student's performance in a variety of academic areas such as reading, ELA, mathematics, science, and history measured by a variety of achievement tests (Davis et al., 2006). Basic skills in language arts and mathematics are extremely important as they are the building blocks for other subjects, but they are not sufficient for elementary students. There is also a need for elementary students to achieve at a high level in other fields, especially science, in order for them to inquire, discover, and draw meaningful inferences of the world around them and transform them into a science literate adult.

Defining Science Achievement

What does it mean for students to achieve in a subject matter domain like science? Using more than 50 years of research on high-quality elementary science to guide them, Michaels et al. (2008) defined science achievement as a connection between both the science content and process skills. They define high-quality science achievement as occurring when "conceptual understanding is linked to the ability to develop or evaluate knowledge claims, carry out empirical investigations, and develop explanations" (p. 35). Students can demonstrate achievement in science by showing proficiency in each of the following four strands: (a) understanding scientific explanations; (b) generating scientific evidence; (c) reflecting on scientific knowledge; and (d) actively participating productively in science (Michaels et al., 2008; NRC, 2012). These four strands were used by the National Research Council (2012) to develop a framework for K-12 science education. This framework was then used to guide the development of the Next Generation Science Standards (NGSS Lead States, 2013) which has been adopted in 20 states and adapted in 24 other states across the nation.

Strand 1: Identifying and Understanding Scientific Principles and Explanations

Identifying science principles incorporates skills like observing, helping build connections among closely related science content like biology and chemistry, and developing interpretations and explanations of scientific principles (National Center for Educational Statistics [NCES], 2021). Students need to be taught how to apply and connect new knowledge to prior knowledge, interests, and experiences to show an understanding of both factual and conceptual science knowledge (Symeonidis & Schwarz, 2016).

Strand 2: Generating Scientific Evidence to Make Sense of the Natural World

The second strand focuses on scientific reasoning using evidence which embeds argumentation (Zembal-Saul, 2009). Students develop knowledge and skills to guide them in building and refining explanations, designing and analyzing investigations, and constructing and defending arguments (Michaels et al., 2008). Students need to start by investigating, interpreting, and communicating their explanations of their natural world. Students should not just be taught to simply memorize facts and definitions, but instead their learning should focus on making sense of the content they are exploring (Hettinger, 2014).

Strand 3: Using Science Inquiry to Reflect on Scientific Knowledge

Students begin to understand that scientific knowledge builds over time and can be revised as new evidence emerges by experiencing science inquiry in the classroom. Scientific inquiry is a complex and time-intensive process that is iterative rather than linear (National Center for Educational Statistics [NCES], 2021). Students should recognize characteristics of inquiry in their own predictions, questions, or explanations as they revise their thinking based on newly observed evidence, increased content knowledge, or development of a new model (Michaels et al., 2008). Science inquiry also allows students to exhibit the habits of mind like curiosity, openness to new ideas, and informed skepticism that are part of science literacy (Roberts & Bybee, 2014). Students focus on questions that allow them to focus on 'knowing how' rather than simply 'knowing what' (Probosari et al., 2017).

Strand 4: Participating Productively in Science

Students should develop a proficiency in science from their participation. At a mastery level, students should be able to represent their scientific ideas, use scientific tools, and communicate about science with their peers (Michaels et al., 2008). Communicating in science allows students to ask questions, convey ideas, and explore their wonderings in science through a shared approach (Queenan, 2011). Actively participating in science will increase students' engagement and promote meaningful learning experiences (Edwards & Mercer, 2013).

Measuring Science Achievement

There are few measurement instruments universally used to assess elementary science achievement in the United States. Students participate in the National Assessment of Educational Progress (NAEP) in fourth grade throughout the country. Students also are tested on an annual statewide assessment in science at least once while in grades 3, 4 or 5 per The Every Student Succeeds Act (ESSA) (Klein, 2018). The ESSA does not provide the metrics that should be measured or what specific content should be assessed to measure elementary science achievement. As such, each state is left to their own accord to determine the specifics of what should be measured and assessed (Klein, 2018). The NAEP has helped states determine the specifics by outlining some metrics to measure student achievement in the discipline of science.

National Assessment of Educational Progress Science Assessment

In the United States, the NAEP is used as a national tool aligned to National Science Education Standards (National Center for Educational Statistics [NCES], 2021) to measure science content knowledge and science practices. Content knowledge is measured in the areas of Earth, space, physical, and life science while the practices describe how students use their science knowledge by measuring what they are able to do with the content. The four science practices assessed on the NAEP are similar to the work of Michaels et al. (2008): (a) identifying science principles; (b) using science principles to make sense of the natural world; (c) using science inquiry to understand about the nature of science; and (d) using technological and engineering design processes.

The NAEP science assessment is a comprehensive test that contains paper-pencil items, hands-on performance tasks, and interactive computer tasks and is given every four years in the fourth grade. The most recent NAEP science assessment was given in 2019 to approximately 30,400 fourth graders across the nation (National Center for Educational Statistics [NCES], 2021). The results from 2019 show that fourth graders were lower by 2 points compared to 2015, while the score was higher by 1 point compared to 2009.

NAEP scores are also available at the state level (National Center for Educational Statistics [NCES], 2021). Although the NAEP test is a good test providing a big picture of how schools are performing at the state and national level, it is not particularly useful for providing student, building or even district-level data. However, the practices assessed on the NAEP test coincide with the definition of student science achievement and the scores can help when state departments are revising science standards and developing state-wide curriculum.

State Standard Achievement Test

Per federal law, the ESSA dictates that a science state standard achievement test (SSAT) is given annually to elementary students in either 3rd, 4th, or 5th grade. States provide scores for individual students, classrooms, schools, and districts. Traditionally, states administered SSATs that did not measure higher-order thinking skills and focused mostly on recall and memorization (NSTA, 2018). This led to concerns that high-achievement by students on these assessments may be only identifying successful teaching to the test compared to truly showing students' understanding of science (Kane & Cantrell, 2013). In the last four years, more states are moving away from administering state science assessments that are composed mostly of recall and basic application of skill/concept questions (Close et al., 2018; Hettinger, 2014). States are now moving to an assessment that measures both factual and conceptual knowledge in a three-dimensional approach (NSTA, 2018).

The current science SSAT, which is being administered in many states, aligns with the NGSS (NGSS Lead States, 2013) and intertwines content with Science and Engineering Practices and Crosscutting Concepts (NSTA, 2018). In this way, science is more than just a set of memorized facts and skills in limited settings; science is composed of themes that cut across and incorporate all science content areas and practices (Mancuso, 2017). Science therefore is a school of thought that allows individuals to comprehend factual science concepts while conceptually using science process skills to gain a better understanding of our complex world to become science literate in our society (Kelana, 2018).

The new structure of SSATs usually begins with a phenomenon or an engineering/design problem. Starting with a phenomenon engages the student in a grade-appropriate, meaningful scientific activity that allows the student to demonstrate his/her ability to think like a scientist and explain the phenomenon or solve the engineering/design problem. This structure focuses on skills while combining a mix of factual and conceptual components to assess students' science achievement. This new test format connects with Michaels et al.'s (2008) definition of science achievement and helps to provide a measurement for achievement that can support teachers in the classroom to develop science literate students.

Elementary Science Student Engagement

Defining Student Engagement

Student engagement is not an easy term to define. Early studies defined student engagement primarily by observable behaviors such as participation and time on task (Brophy, 1983; Natriello, 1984). One of the earliest theories of engagement, the participation-identification model (Finn, 1989), defined engagement in school as having both a behavioral component, like participation, and an emotional component. Another influential engagement model was developed by Connell and his collaborators who distinguished two ends of the engagement continuum, students being engaged and disengaged (Connell, 1990; Connell & Wellborn, 1991). Engaged students are defined as being attentive and participating in class discussions, exerting effort in class activities, and exhibiting interest and motivation to learn (Fredricks et al., 2016; Marks, 2000). Students are engaged when they are involved in their work, persist despite challenges and obstacles, and take visible delight in their work (Schlechty, 2001). In contrast, disengaged students are passive, do not put forth effort, are bored, and give up easily (Skinner & Belmont, 1993). Disengaged students become more disruptive, have lower grades, are more anxious, and are more likely to drop out of school (Kaplan et al., 1997; Skinner & Belmont, 1993). Student engagement in the classroom is a key factor in enhancing student achievement (Garcia-Reid et al., 2005; Reyes et al., 2012); therefore learning is contingent upon the extent to which students are engaged in classroom learning activities (Chen, 2005).

Fredricks et al. (2004, 2016) created a current classroom engagement model that considers three distinct, yet interrelated dimensions – behavioral, emotional, and cognitive engagement. Each of the three dimensions of engagement have positive effects on student achievement. Below, all three of these dimensions are briefly defined and show examples that demonstrate how this type of engagement can be measured in a classroom, and how student achievement is impacted.

Behavioral Engagement

A goal of many elementary teachers is to motivate students to participate through actions in their own learning process, which is known as behavioral engagement. In the literature, behavioral engagement is defined in terms of involvement in academic and class-based activities, effort, attention, positive conduct, and the absence of disruptive behavior (Fredricks et al., 2004). Previous studies have measured behavioral engagement by students and focused on displays of effort, persistence, behavioral aspects of attention (such as making eye contact, leaning forward during discussions, etc.), assignment completion, and self-directed academic behavior such as purposefully asking questions and seeking out information without prompting or assistance (Buhs & Ladd, 2001). By using a relevant phenomenon during instruction, students are actively “drawn in” to ask questions, wonder, and have engaging discourse with their peers to determine the explanation of what causes the phenomenon (Mancuso, 2017). The link between behavioral engagement and student achievement has been robust within educational research (Fredricks et al., 2004, Guo et al., 2015: Marks, 2000) and shows a positive correlation between these two factors.

Emotional Engagement

Emotional engagement is defined as students’ emotional reactions to academic subject areas, like science, as well as valuing learning and having interest in the learning content (Pekrun & Linnenbrink-Garcia, 2012). This type of engagement focuses on creating students' science self-concept, which refers to a student’s belief that they can learn and understand science (Grabau & Ma, 2017). Parents, peers, and teachers influence the formation of science self-concept and it is measured by how students understand newly presented science ideas, how students answer questions about science, and how confident they feel about what they have learned (Grabau & Ma, 2017). Having an enjoyment of science, which is a student's feeling of fun and happiness when engaging in science learning activities, also reinforces emotional engagement (Fredricks et al., 2004). Using phenomenon-based teaching strategies, teachers can create an enjoyment of science by developing positive relationships through student collaboration, implementing active science instructional strategies (e.g. hands-on learning, active questioning), and showing enthusiasm when teaching about relevant scientific events. Some of the components of emotional engagement that can be observed in the classroom are: a) the extent of both positive and negative reactions to teachers, classmates, or academics, b) emotional reactions such as interest, enjoyment, and the individual’s sense of belonging. A positive relationship has been found between emotional engagement and achievement (Perkum & Linnenbrink-Garcia, 2012). Students who report higher levels of positive emotions when learning, score higher on measures of learning and conceptual change assessments (Heddy & Sinatra, 2013). As defined by the NGSS (NGSS Lead States, 2013), conceptual change is a process that results in a paradigm shift, revolutionizing one’s prior thinking by replacing a misconception with a scientifically acceptable concept. Conceptual change assessments can help identify students' awareness of scientific misconceptions and attitudes towards specific concepts while assessing how they confront their prior beliefs to make a change in their learning and attitudes (Sinatra et al., 2014).

Cognitive Engagement

Cognitive engagement is defined in terms of self-regulated learning, using deep learning strategies, and exerting the necessary cognitive strategies for comprehension of complex ideas (Zimmerman, 1990). A student becomes invested when they expand cognitive effort in order to understand, go beyond the requirement of the activity, and use flexible problem solving while understanding a difficult task (Fredricks et al., 2004). Cognitive engagement has been measured by looking at the use of shallow and deep learning strategies to understand material, students self-regulating, students setting learning goals, and students persisting on challenging tasks (Capella et al., 2013; Corno & Mandinach, 1983). Phenomenon-based teaching strategies promote a deeper understanding of the science concepts by incorporating relevant phenomena. The phenomena challenges students to question and wonder about observable events which in turn engages them in developing a clearer understanding. Cognitive engagement has been shown to directly predict achievement and can lead to increased motivation (Guthrie et al., 2004).

Components of Student Engagement

A common question asked by educators is, “How can I actively engage students in my classroom?” Students are engaged when they devote time and effort to a task, care about the quality of their work, and commit to the learning because of the significance of the task (Antonetti & Garver, 2015). Teachers can foster student engagement by providing the following components in their classroom: (a) create a culture of achievement; (b) develop interactive and relevant lessons that build student interest; and (c) build student self-efficacy by supporting and encouraging students to learn. Each of these three components is discussed in more detail below and how integrating phenomenon-based instruction can help support engagement.

Creating a culture of achievement in a classroom occurs when the teacher provides instruction that is challenging, allows students to feel comfortable asking questions, and expects students to put forth their best efforts (Jackson & Zmuda, 2014). When students feel challenged, they are less likely to be bored and disengaged. Challenging instruction is rigorous, aligns with content standards, and uses strategies to meet the needs of all students (Weiss & Pasley, 2004). Phenomenon-based teaching is challenging because students are introduced to a unique, real-life event that they must explore, ask questions about, research, and collaborate to gain a better understanding. Teachers can also create a culture of achievement where learning is perceived as important and asking questions is not only accepted, but expected. Having students ask questions is an integral part of meaningful learning and science inquiry. The formation of asking good questions is a creative act, and at the heart of what doing science is all about (Chin & Osborne, 2010). Having students ask questions and wonder is fundamental to phenomenon-based teaching. Teachers play an important role in helping create a culture where students feel comfortable and successful posing questions as they reason, problem-solve, and think critically on the phenomenon and the science content being taught.

Another component of fostering student engagement is to develop interactive and relevant lessons that build student prior knowledge. Examples of instructional strategies to support student engagement include group activities, hands-on experiences, and lessons that draw from students' backgrounds, interests, and academic needs (Fredricks et al., 2019). Drawing connections between information taught and real life events is highly effective in engaging students (Heller et al., 2012). Research has also shown that supporting students' interests in the learning process increases student engagement (Akey, 2006). In phenomenon-based instruction, a relevant event is shown and students collaboratively ask questions while using their prior knowledge to connect science concepts to the event. As phenomena are introduced, students are actively building background knowledge while discussing the 'what, how and whys' of the phenomena with the other students in the classroom (Almarode & Vandas, 2019). Student engagement is stimulated by students having a "stake" in the learning process using relevant and interesting phenomena.

In the science classroom, fostering support and encouragement for students to learn will help develop students' science self-efficacy (Mintzes et al., 2013). Science self-efficacy refers to a student's confidence in performing science-related interactive tasks (Grabau & Ma, 2017). Learners can increase their self-efficacy from actual performances that are hands-on, incorporating discussion of the science with peers, and having both teachers and students provide feedback on their specific achievement on a science task (Bandura et al., 1997). Self-efficacy in science can be supported in a phenomenon-based classroom, because the phenomenon introduced can create student driven questions, provide opportunities for interacting with others, and allow for student choice (Antonetti & Garver, 2015).

Measuring Student Engagement

Many different kinds of evidence have been used to demonstrate that students are engaged in elementary classroom activities. Past research has focused on measuring engagement through the use of self-report questionnaires (Meece et al., 1988) or through observations of individual students during classroom lessons (Lee & Anderson, 1993). Nystrand and Gamoran (1991) took a different approach by suggesting that instructional discourse itself should be an important source of data on student engagement. Herrenkohl and Guerra (1998) were among the first researchers to postulate changes in engagement as changes in discourse occurred within the context of science. Their analysis focused on how individual students become actively engaged in discussion and argumentation through the process of generating, manipulating, and constructing ideas. They defined being engaged as learning as members of a community while developing a collective sense of purpose and accomplishment. Engle and Conant (2002) took this notion even further by stating that engaging in science means that students ask questions and argue for the methods of seeking evidence to produce claims. By emphasizing argumentation within a relevant phenomenon, these researchers claim to be able to unfold and capture how individual students develop both cognitive and behavioral engagement. Because of this, engagement can be viewed in terms of discourse practices that extend beyond just the behavior of individual students and instead involves the social interaction of a group of students.

Through this study, engagement will be viewed in terms of discourse practices. Students will contribute to their community by taking on roles and responsibilities as they ask questions and make sense of the phenomena presented (Holland & Lave, 2009). Capturing student participation and discourse is essential because knowledge is believed to be built upon and distributed in the context of the phenomena (Ryu & Lombardi, 2015). Hatano and Inagaki (1991) pointed out three discourse practices being central for successful group discussion and development of student understanding. These practices can be taken into account when developing discourse measurement protocols for elementary science:

1) Clarification - By having students ask clarification questions to each other, they can fully understand the perspectives proposed by other students. Clarifying questions encourage dialogue and promote the establishment of shared meaning or common knowledge in the classroom context (Edwards & Mercer, 2013).

2) Disputing - Can also be called "challenging others." Challenging questions raise queries about the plausibility of scientific arguments and begin debates about how one might think about a phenomenon (Herrenkohl & Guerra, 1998). This practice shows a high level of engagement because students can openly discuss and decide for themselves among different claims and perspectives of the same phenomenon.

3) Coordinating knowledge with evidence - For students to construct well-grounded scientific arguments, students must learn how to coordinate their theories with supporting evidence. By initiating discourse that deals with

coordinating theories and evidence, students are enacting a social practice common to what takes place in science communities (Harbour et al., 2015).

Summary of Literature Review

Achievement and engagement in science learning can be seen as a dynamic process between the individual and the disciplinary practice within a community (e.g., a science classroom; Ryu & Lombardi, 2015). Three components of phenomenon-based instruction; discourse, argumentation, and sensemaking, can create opportunities for behavioral, emotional and cognitive engagement to occur in the classroom while improving academic achievement. The purpose of this study is to explore how the use of phenomenon-based instruction in elementary science lessons affect student achievement and engagement in science content learning. The study builds upon existing research in phenomenon-based instruction to deepen the understanding of the relationship between phenomenon-based instruction and student achievement. By focusing on elementary science instruction, the study will add to an area that has not yet been deeply explored in the literature. The study compares achievement of both factual science content knowledge and conceptual skill based knowledge. Exploring this as an element, marks new and important research in determining how phenomenon-based instructional practices affect achievement. Further the study examines the connection between student engagement and components of phenomenon-based instruction. Concentrating on student engagement in elementary science classrooms through analyzing students' discourse has been almost nonexistent in the research and this study will contribute to examining a pedagogical approach that can improve elementary student engagement.

CHAPTER THREE: METHODOLOGY

The purpose of this mixed-methods study is to determine how phenomena-based instruction impacts student achievement and engagement in the elementary science classroom. The questions addressed in this study are:

Question 1: How does phenomenon-based instruction affect student achievement in elementary science?

Question 2: How does phenomenon-based instruction affect student engagement in elementary science?

Mixed Methods Design

A mixed methods study is when both quantitative and qualitative data are collected and analyzed rigorously by a researcher in response to research questions and hypotheses (Creswell & Clark, 2018). According to Johnson, Onwuegbuzie, and Turner (2007) "mixed methods research combines elements of qualitative and quantitative research approaches for the purposes of breadth and depth of understanding and corroboration" (p. 123). Creswell and Clark (2018) defined the role of the researcher in mixed methods research as one who:

- Collects and analyzes both qualitative and quantitative data rigorously in response to research questions and hypotheses
- Integrates (mixes or combines) the two forms of data and their results
- Organizes these procedures into specific research designs that provide the logic and procedures for conducting the study.

The benefit of mixed methods research is the combination of both quantitative and qualitative methods which provides opportunities for the limitations of one method to be compensated for by the strength of the other method. Mixed method research provides better inferences and minimizes unimethod bias (Creswell & Clark, 2018). Many researchers select mixed methods in order to search out the opportunity for a greater assortment of divergent views (Subedi, 2016).

The mixed methods research design for this study was an explanatory sequential mixed method (Creswell & Clark, 2018). An explanatory sequential design consists of first collecting quantitative data and then collecting qualitative data to help explain or elaborate on the quantitative results and is illustrated in Figure 2 (Creswell & Clark, 2018).

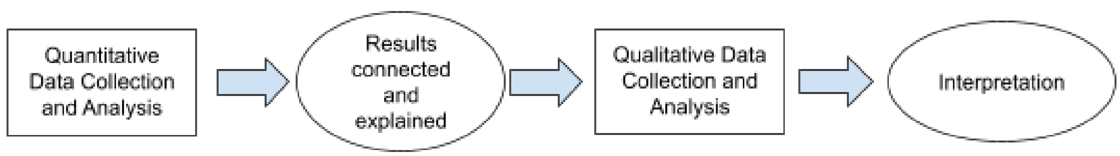

Figure 2. Explanatory Sequential Design

The rationale for this approach is that the quantitative data and results provide a general picture of the research problem. However, this design recognizes that more analysis - specifically through qualitative data collection - is needed to refine, extend or explain the general picture (Subedi, 2016). The explanatory sequential design has two phases of data collection and analysis: Phase One - quantitative and Phase Two - qualitative.

Research Design Phase One: Quantitative

In an explanatory sequential mixed method research design the collection of the quantitative data takes place as an initial step. First, the sample, setting and procedure are defined. Second, the instrument used will be described for the quantitative phase. Lastly, the descriptions of the statistical approaches are elaborated on and the instrument's validity and reliability discussed.

Sampling and Setting

The study was first presented to a group of public-school teachers whose names were obtained at the district level where the research was conducted. From the group of interested teachers, four teachers were chosen to participate in the study. The researcher specifically selected the four teachers through purposeful sampling. According to Merriam (1998):

> The logic and power of purposeful sampling lies in selecting information-rich cases for study in depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the term purposeful sampling (p. 61).

This type of sampling helps eliminate a number of external variables, and helps focus on the educational instruction method. These variables include different grades, different school district curriculums, and different participant backgrounds.

To begin purposeful sampling, the researcher first determines what selection criteria are essential in choosing the participants to be studied (LeCompte et al., 1993; Merriam, 1998). Four inclusionary criteria were used to determine the teachers selected:

1) Teacher had to teach fifth grade students exclusively (no combination of classrooms).
2) Teachers had to be in the same school district and use the same district science curriculum.
3) Teachers had to be interested in the professional development that accompanied the study.
4) Teachers had to agree to randomization.

To avoid a selection bias, all participating teachers interested in receiving professional development on phenomenon-based instruction were randomly assigned to the control and treatment groups. One teacher at each of the participating schools was randomly selected to receive professional development on phenomenon-based instruction before the study commenced; the other teacher received the professional development after the study was completed. All names and identities of the teachers were kept confidential and that confidentiality was maintained by coding the data so that only the researcher knows the names of the individuals involved in the study.

The study was conducted in an urban, public school district located in the Northwest. Using purposive sampling (Etikan et al., 2016), four fifth grade classrooms in the same school district were selected at two elementary schools. Both schools in the study had only two fifth grade classrooms in their building, so every fifth grade student at the two schools were involved in the study. The two schools have been identified for the purpose of this study as Ash Elementary and Sycamore Elementary. From these four classes, 106 fifth grade students participated (47 in the control group, 49 in the treatment group; 47 female and 49 male).

Schools and Teacher Participants

Ash Elementary has the following ethnic demographics: 87% of the students are White, 5% Hispanic, and 2% Black with the remaining 6% unknown to the researcher. 28% of the students qualified for free or reduced-price lunch at Ash Elementary. The two teachers selected to participate from Ash Elementary were Ms. Jones and Mr. Smith. Mr. Smith's class was randomly selected to be the control group and Ms. Jones' class was selected to be the treatment group. Mr. Smith has been teaching elementary school for 13 years and Ms. Jones has been teaching elementary school for 7 years.

Sycamore Elementary has the following ethnic demographics: 83% of the students are White, 9% Hispanic and 3% Black and the remaining 6% unknown to the researcher. 31% of the students qualify for free or reduced-price lunch. The two teachers selected to participate from Sycamore Elementary were Ms. Hawkes and Ms. Wray. Ms. Hawkes's class was randomly selected to be the control group and Ms. Wray's class was selected to be the treatment group. Ms. Hawkes has been teaching elementary school for 13 years and Ms. Wray has been teaching elementary school for 9 years.

Student Participants

The number of students in each individual classroom ranged from 20 to 27 which are average sizes within the school district of Ash Elementary and Sycamore Elementary. To protect students' identities, the only demographic information collected at the classroom level was gender. (See Table 3.1).

Table 3.1. Student participation in each class

	Control Group	Treatment Group
Ash Elementary	Mr. Smith	Ms. Jones
	N = 27 (9 males, 18 females)	N = 28 (13 males, 15 females)
Sycamore Elementary	Ms. Hawkes	Ms. Wray
	N = 20 (11 males, 9 females)	N = 21 (15 males, 6 females)

Procedures

In Phase One of the study, a seven-step procedure was followed.

Step 1: IRB and District Approval to conduct the study

The researcher obtained approval to conduct this research through Boise State University's Institutional Review Board. A copy is found in Appendix F. The researcher then obtained approval from the public-school district's research committee.

Step 2: Identifying fifth grade teachers and two elementary schools

The researcher next sent out a request to district recommended fifth grade teachers at a few schools in the public-school district the research was to be conducted. The goal was to identify four teachers, two to be part of the control group and two to be part of a treatment group. The researcher wanted two schools in the study that had a maximum of two fifth grade classrooms in the school so that one could represent the control group and one could represent the treatment group. The researcher also wanted to purposefully select schools that had similar student demographics and teachers with similar years of experience. The reason for these decisions was the researcher wanted to attempt to minimize the variables of student demographics and teaching experience within the study so the focus could be on the phenomenon-based instructional pedagogy. After looking at all the responses from accepting teachers, Ash Elementary and Sycamore Elementary were chosen because they fit the above requirements for the study.

Once the teachers were selected, the researcher conducted a brief overview discussion with all four teachers about the research study. They were informed that two would be part of a control group and two would be part of the treatment group. Those who were part of the treatment group would receive phenomenon-based instruction training prior to the classroom science unit being taught, and that the two that were part of the control group would be provided the training after the study.

Step 3: Teacher Training

A week before the science instruction was presented to students, an hour-long professional development session was given to both the control and treatment teachers together on the overview of the science standards being taught, the activities the students would be conducting, and the structure of the lessons. Also during this training, the teachers were informed that groups of three to four students needed to be created, so that student discourse could be recorded with iPads located in the middle of randomly selected student groups.

After the initial training, the treatment group teachers (Jones and Wray) received an additional thirty-minute professional development session that focused on the components of phenomenon-based instruction (discourse, argumentation, and sensemaking). The information presented in this professional development session also included the following three components: 1) how teachers use phenomena to promote students asking driving questions instead of teachers asking and answering all the questions, 2) how to implement strategies in the classroom to encourage rich student discourse that ties back to the phenomena (Windschitl et al., 2020), and 3) how teachers can use questioning strategies in the classroom to press students to develop their own claims and evidence instead of the teacher giving students all the science content and answers (McGill et al., 2021).

To ensure treatment fidelity, which is defined as strategies that monitor and enhance the accuracy and consistency of the intervention as planned (Smith et al., 2007), two components were included in the study. First, Hennessey and Rumrill (2003) suggest that providing uniform training procedures helps ensure treatment fidelity. As mentioned above, the control and treatment teachers were together in one location for the one-hour professional development session so that the same message was heard by all participants. Second, both the control and treatment teachers were given detailed lesson plans and a presentation slideshow used during instruction to help guide them through the science lessons with students. The only difference between the lesson plans and slideshows was that the control teachers' plans and slides do not contain phenomenon-based teaching strategies, while the treatment groups lessons and slideshows have phenomena and phenomenon-based strategies embedded throughout (lesson plan and slide shows found in Appendix A). As mentioned by Bellg et al. (2004), having delivery protocols by providing materials and resources with specific instructions help enhance treatment fidelity. Finally, to ensure the fidelity of implementation, the researcher observed all the lessons being taught by both the control and treatment groups to make sure teachers used the materials provided at the professional development session with fidelity.

Step 4: Pre-Achievement Test

The pretest was taken by both the control and treatment groups on the Friday before the science instruction began. The students received the paper/pencil test in their regular classroom setting and the teachers delivered the evaluation over 20 minutes with the following instructions, “For questions 1 - 8 circle the best answer and questions 9 and 10 answer these questions to your best ability.” To preserve anonymity while retaining the ability to connect the pretest to post-test, the students used an identifier code on their test. All the assessment data was stored electronically in a password protected file and all the physical copies of the tests were secured in a locked office. The pretest is found in Appendix B.

Step 5: Classroom Instruction

The week following the pre-test, students were taught five daily 40-minute 5-E science lessons using fifth grade physical science standards from the Next Generation Science Standards. These particular standards were chosen because it is the first major science unit of the year for each teacher. The standards taught during the week were:

1) Students will make observations and measurements to identify materials based on their properties. (Next Generation Science Standard 5-PS1-3)
2) Students will conduct an investigation to determine whether the mixing of two or more substances result in a new substance. (Next Generation Science Standard 5-PS1-4)

The science instruction given to all the students during the week followed a detailed lesson framework that incorporated the 5-E instructional model in which all four teachers were knowledgeable and trained (Bybee et al., 2006). Table 3.2 shows an overview of the 5-E model while the complete lesson plans for both the control and treatment group are found in Appendix A. The 5-E lessons are divided into five phases with descriptive titles: Engage, Explore, Explain, Elaborate, and Evaluate. Below is an overview of how each of the 5-E components were presented during the professional development for both the control and treatment group teachers.

ENGAGE STAGE: Engagement activities are designed to capture students' attention. For the control group lessons, this includes asking students direct questions to tap into their prior knowledge and discussing what will be learned in the lesson. For the treatment group, the engagement stage begins by using a relevant phenomenon to activate prior knowledge while helping students make connections between past and present learning. Students, instead of teachers, drive the questions like "Why did this happen?" "What do I already know about this?" "What can I find out about this?"

EXPLORE STAGE: Exploration gives students an opportunity to actively plan and engage in hands-on activities to make observations, gather evidence, and collect data (Brown, 2019). Both the control and treatment group are presented the same hands-on activity. The main difference between the control and treatment groups during this stage is the treatment group teacher's role is to facilitate learning using phenomenon-based strategies. Some of the strategies that will be used during this time include incorporating talk moves (O'Connor & Michaels, 2019; Windschitl et al., 2020) to help encourage student to student interaction while asking probing questions to help students make sense of their experiences.

EXPLAIN STAGE: Key scientific concepts and vocabulary are explained in this phase. In the control and treatment groups, explaining the concepts is driven by the teacher who is overall presenting the information and science vocabulary needed to help students understand the science content. However, the treatment group teacher will ask a few more teacher-guided questions that focus on analyzing and discussing student observations and models, encouraging students to generate explanations, and allowing students to create science vocabulary definitions by connecting their own claims and evidence back to the phenomena presented at the beginning of the lesson.

ELABORATE STAGE: Elaboration gives students the opportunity to expand and solidify their understanding of science by providing opportunities to apply their ideas to a new context. This stage is helpful for both the control and treatment group to determine if students still have misconceptions or if they can only understand the science concepts in terms of the exploratory experience instead of applying it to different situations. The difference in instruction between the groups at this stage is that the control teachers will attempt to apply the concepts to a brand new application while the treatment teachers will use the phenomenon from the beginning of the lesson to expand and apply the context of that situation. The treatment group students will continue to ask wondering questions to expand their thinking on the phenomenon.

EVALUATION STAGE: Evaluation can include both formative and summative assessments to not only determine what the students have learned, but to also give students feedback on their learning. In three of the five lessons, both the control and treatment group students use claim, evidence, reasoning (CER) scenarios that tie back to the concepts taught as an assessment tool. There are no real differences in instruction during the evaluation stage between the control and treatment group. The only difference is the questioning techniques from the teachers. In the control group, the teacher will use traditional questions found in most textbooks to evaluate learning, like “How would you define…?” “Where is this located?” “Describe what happened when…?” The treatment group will use the original phenomenon to ask open ended questions like “Why do you think…?” “What evidence do you have?” “How can you connect what happened in this phenomenon to something else on Earth?”

Table 3.2. Overview of 5-E Model

5-E Component	Control Group	Treatment Group
Engage	Explanation of what students will be learning; direct questions from the teacher to activate prior knowledge (ex - What is a property?")	Relevant phenomenon shown to students. Teacher asks open-ended questions to connect prior knowledge to content (ex- why do you think this happened?; what questions do you have?")
Explore	Hands on activity that is guided by teacher directed procedures and questions.	Hands on activity that incorporates talk moves to encourage students asking probing questions.
Explain	Teacher presenting science vocabulary in a direct teaching model.	Teachers present vocabulary while facilitating student discussion that allows students to connect experiences to apply vocabulary to the phenomenon.
Elaborate	Students apply what they have learned to a different situation while the teacher determines if students still have misconceptions.	Students apply what they have learned to the original phenomenon that was presented at the beginning of the lesson. The teacher determines if students still have misconceptions.

Evaluate	Teachers will use formative and summative assessments that include typical textbook questions like; How would you define…; Describe what happened?	Teachers will use formative and summative assessments that relate back to the phenomenon and ask questions like; Why do you think this happened and what is your evidence?

All five of the lessons were structured and built on previous skills learned throughout the week. An overview of the essential question and student activities in each lesson are listed in Table 3.3.

Table 3.3. Overview of activities in science lessons

Day and Essential Question	Overview of Student Activities included in Lesson
Day 1: What are different ways to classify matter?	• Open sort to classify based on properties • Create a Tree Map • Describe the mystery object
Day 2: How can physical properties be used to identify matter?	• Investigation to identify white powders • Argumentation discussion • CER on mystery powder
Day 3: How can the properties of magnetism, conductivity, and reflectivity be used to identify matter?	• Investigation using specific properties • Literacy connection reading an article • CER on which balloon has iron
Day 4: What is the difference between a physical and chemical change?	• Changing paper demonstration • Station investigation on changes • Double Bubble map • CER on what kind of change is rust
Day 5: How do baking soda and baking powder react differently?	• Investigation with baking soda & baking powder • Which is which game - physical or chemical change • Post Assessment

Step 6: Post-Achievement Test

The posttest was taken by both the control and treatment groups on the Friday after the last science lesson was presented (one week after the pretest). The students received the paper/pencil test in their regular classroom setting and the teachers delivered the evaluation with the following instructions, "For questions 1 - 8 circle the best answer and questions 9 and 10 answer these questions to your best ability." To preserve anonymity while retaining the ability to connect the pretest to post-test, the students used an identifier code on their test. All the assessment data was stored electronically in a password protected file and all the physical copies of the tests were secured in a locked office. The posttest is found in Appendix B.

Step 7: Quantitative Data Collection & Analysis

The final step was to analyze the data from the pretest and posttest and begin analysis. The analysis sought to determine if there was a positive correlation to phenomenon-based instruction (the treatment groups) and student achievement.

Quantitative Data Collection

As described above, this study made use of intact classrooms; therefore, this is a quasi-experimental study. Student achievement was compared across the control and treatment group, and also compared across the pretest and posttest. The instrument used to collect achievement data for the study was a pre/post-test that included both factual and conceptual knowledge questions; note that the pre and posttests are identical. The test was created using both a current school district test bank and sample test questions from a variety of state science achievement tests. All the items on the test directly align to the NGSS standards, which allows students to demonstrate their mastery of science and engineering practices and the cross-cutting concepts within the standards for fifth grade physical science. The assessment included ten questions: eight multiple-choice questions that focused on content knowledge and two free response questions that focused on conceptual knowledge. The test included topics related to physical properties of matter, changes in matter, and science process skills like analyzing data, making observations, and developing claims with evidence. The pre-posttest is found in Appendix B.

For the first eight multiple choice questions, each individual question was given one point for a correct answer and a zero for an incorrect answer. Correct explanations on the last two free-response conceptual questions were evaluated with an assertion rubric that is similar to the rubrics used on the state science assessments. Complete assertion rubric is found in Appendix C. For conceptual question number nine, three points were recorded for completely correct answers, followed by two and one points for partial correct answers as followed by the assertion rubric. Complete wrong answers were evaluated as zero points. For conceptual question number ten, four points were recorded for completely correct answers, followed by three, two and one points for partial correct answers. Complete wrong answers were evaluated as zero points.

Quantitative Data Analysis

To examine the effect of phenomenon-based teaching on student achievement a two-way analysis of variance (ANOVA) design was used. The two-way ANOVA is a statistical test to analyze the difference between the means of more than two groups. A two-way ANOVA is used when two independent variables, in combination, affect a dependent variable. The purpose of performing an ANOVA is to compare groups that are exposed to separate levels of variables and to see to what extent there is a difference in the dependent variable between the two groups (Rutherford, 2011). ANOVA is considered to be the extension of *t*-test (Rutherford, 2011) as it examines the difference between groups simultaneously. The purpose of a one-way ANOVA test is to determine differences between means for one independent variable across two or more levels

(Shavelson, 1998). The purpose of using a two-way ANOVA is to determine if the independent groups have statistically significant differences between the means as it tests the null hypothesis (Jackson & Brashers, 1994; Upendra et al., 2017). The effect size of a two-way ANOVA is computed by finding the difference between the group means and dividing by the controlled group's standard deviation (Cortina & Nouri, 2000). The two-way ANOVA is used when a measurement variable and at least two nominal variables are present. A two-way ANOVA was used in this study to assess differences in classroom groups that used traditional versus phenomenon-based instruction as it relates to student achievement based on pre and posttest assessments. The first group (classroom: control versus treatment) by the second group (time: pretest versus posttest), with student achievement as the dependable variable. See Table 3.4

Table 3.4. Two-way ANOVA

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Independent Variable 2: (Time)</th></tr>
<tr><th>Level 1 (pretest)</th><th>Level 2 (posttest)</th></tr>
<tr><td rowspan="2">Independent Variable 1: (Classroom Groups)</td><td>Level 1 (control)</td><td>Dependent variable: (student achievement)</td><td>Dependent variable: (student achievement)</td></tr>
<tr><td>Level 2 (treatment)</td><td>Dependent variable: (student achievement)</td><td>Dependent variable: (student achievement)</td></tr>
</table>

This analysis compares the student achievement across the control and the treatment group, as well as across pretest and posttest. Separate ANOVAs were conducted for both factual and conceptual knowledge. The results from the two-way ANOVA test provided the foundational data for Phase Two of the study. Upon the collection, analysis, and interpretation of the quantitative data, phase two of the research design was crafted to help provide more answers for the research questions.

Research Design Phase Two: Qualitative

In an explanatory sequential mixed method design the qualitative data collection of the research study takes place as a second step. After reviewing the quantitative data and not having a clear picture of how phenomenon-based instruction impacted student conceptual achievement and engagement, the qualitative design was crafted to complement the quantitative data. In this study, qualitative data collection was conducted at two different times. First, data was collected during the science week instruction, recording students during the lesson. Second, questionnaires were crafted after the quantitative data was analyzed and given to the four teachers. The qualitative data was analyzed and interpreted after the quantitative data to gain deeper insights. The researcher employed a basic interpretive qualitative research design in order to discover and understand the perspectives of students and the teachers in the classroom (Merriam & Grenier, 2019). One of the key characteristics of basic interpretive qualitative research is to understand the meaning people have constructed about their world and their experiences. Because this study sought to understand how students made sense of science through the lens of phenomena-based learning and its impact on their engagement and overall knowledge acquisition, this particular design is the most appropriate.

Qualitative researchers have not reached a consensus regarding the number of participants to be selected for a basic qualitative study (Merriam, 1998). What is generally accepted is that the number of participants should be selected until a point of saturation or redundancy is reached in the information (Creswell, 2017; Lincoln & Guba, 1985; Merriam, 1998). In the following section, the data collection and analysis procedures are discussed.

The goal of this study was to take the narrative and non-textual information to add meaning to numeric data, while the numeric data added precision to narrative and non-textual information. One portion of the qualitative data was collected in between the pretest and posttest, although it was not analyzed until after the quantitative data was interpreted. The other portion of the qualitative data was collected at a later time because some questions were still not answered. The results of the quantitative data provided the needed information to design the qualitative study by identifying what words and phrases to focus on and what questions to ask the teachers. Without the quantitative data, the qualitative section would not have been developed the way that it was.

Qualitative Data-Collection

In a basic interpretive qualitative study, data can be collected through many means (Merriam & Griener, 2019). Trustworthiness was established through triangulation (Merriam, 1998; Rossman & Rallis, 2003). The purpose of triangulation is to check the integrity and the validity of the research results that a researcher finds by checking with multiple data sources, methods, theories, or investigators (Schwandt, 2015). "A major strength of triangulation is the integration of multiple forms of evidence, various perspectives, and different analytic strategies; such integration can yield more meaningful research findings than any single approach" (Briller et al., 2008, p. 246). In this study qualitative data were collected from three different sources and evaluated by the researcher: (1) discourse analysis from recordings of students during classroom instruction, (2) transcription of statements made by the participating students and (3) observations by the researcher and from the participating teachers. The process of triangulation is important because it provides evidence that the criterion of validity was met and provides a means of checking the integrity of the inferences the researcher drew upon (Schwandt, 2015).

Data Source One: Student Discourse Analysis

The first source of data collected was over 40 hours of audio recordings on multiple iPads placed around the classroom in the middle of small groups of students. The iPads were randomly placed during each daily lesson in both the control and treatment groups.

Data Source Two: Student Statements

The second source of data collected were statements from student participants during classroom instruction. The statements were collected from the iPad recordings and later transcribed by the researcher. The researcher coded student statements that demonstrated a development of connections to what they were learning to something relevant. For example, the researcher listened for ways students made sense of what they had learned by applying their knowledge to different situations.

Data Source Three: Observations

The final source of data was obtained from two sources of observations: the researcher's observations during the science instruction and the teacher's observations after the science instruction. The researcher's observations were focused on student interactions and noted during and directly after the science lesson was completed. Based on the quantitative data to gain a better understanding of both research questions, a questionnaire was provided to the teachers after the science instruction took place. The strength of this questionnaire was that it did not intrude, influence, or alter the classroom setting in a way they had known this was going to be asked (Merriam & Tisdell, 2016). The purpose of the questionnaire was to gather teacher's observations around student achievement and engagement.

All three of these data sources aided in confirming the quantitative data collected in Phase One of the study and provided a better explanation of the quantitative results.

Qualitative Data Analysis

The analysis of the data collected in Phase Two of the study followed the traditional five step process:

Step 1: Preliminary Analysis

The first step, at the suggestion of Merriam (1998), was to conduct a preliminary analysis after the week of science instruction was concluded. The purpose of the preliminary analysis was to explore the data so a general sense of the information could be obtained, to consider whether more data was needed, and whether this method did indeed complement the quantitative data that had been collected and analyzed in Phase One. During this preliminary analysis, the quantitative data was collected, analyzed, and interpreted which helped the design of the qualitative study.

The preliminary analysis process was conducted for each classroom that participated in the study. The process allowed for a better understanding of the data that was collected. Through this first step, a preliminary analysis uncovered areas of specific focus which supported the quantitative findings.

Step 2: Focusing on the Research Questions

During the second step, the researcher reviewed the data and focused on the research questions for both student achievement and engagement. This focus took place to see the diversity of the dimensions in each category. According to Strauss and Corbin (1998), the art of comparison relates to the creative processes and the interplay between data and researcher when gathering and focusing take place. Qualitative research allows the researcher to explore with the participants through the dialogue that takes place. During this step, the second researcher once again assisted. The importance of the second researcher in this step was to assure the data was being captured and documented properly. During this step, three specific items were analyzed from qualitative data.

After all science lessons were completed, the recordings were listened to by two researchers, the key researcher and a second researcher to enhance the rigor of qualitative data analysis.

The researcher looked for an observational instrument analyzing elementary student discourse that would measure engagement in science, but the search failed to produce an instrument that also included components of phenomenon-based instruction. Subsequently, an instrument was designed by the researchers to record the components of phenomenon-based inquiry (Appendix E).

Discourse analysis helps provide an understanding of not only how learning is constructed, but how engaged students are in the discussions (Gee & Green, 1998). Discourse analysis shows how students ask questions and negotiate norms that motivate their ongoing engagement in the contexts in which the science activities and content occur (Ryu & Lombardi, 2015). The recordings were examined specifically for the number of questions asked by students, the number of times students used specific physical science vocabulary in their discussions, and the number of times students made claims with evidence. Teachers promoted discourse by allowing time for students to ask questions, use science practices in hands-on investigations, and incorporate whole group discussions to build connections between students' prior knowledge and the science content being taught.

To enhance interrater reliability, the two researchers began by listening to day one of the recordings together to develop clear definitions and examples of questions, vocabulary, and claims/evidence. The two researchers then listened independently to the rest of the recordings and compared and discussed their independent analyses to build a clear and concise understanding of what they heard from the recordings. Any disagreements were highlighted and the raters' analyses and code clarification resulted in approximately 90% agreement.

The first item analyzed was the number and type of science related questions asked by students, either directly to the teacher or to other students in their group. The student questions that were tallied dealt specifically with science concepts or science practices directly related to the lesson and did not include unrelated questions like "What is for lunch today?", and "Did you hear about what happened on the playground?" The researchers tallied the number of questions heard on the recordings for each group and then came together to compare their findings. If a different number of questions for a particular group was recorded by the researchers, both researchers went back and listened to the recording together to identify the number of science questions asked.

The second item analyzed was the number of science vocabulary words students talked about during the lesson. Students using science vocabulary allows them to participate and engage in the content being delivered (Erduran et al., 2004). The researchers tallied the number of times they heard specific physical science vocabulary words (found in Appendix E) on the recordings for each group and then came together to compare their findings.

The third item analyzed was listening for the number of statements where students used evidence to defend their claims. Students using argumentation practices like using evidence to defend claims (Zembal-Saul, 2009), show students are using social constructivist principles which support students' cognitive engagement (Fredricks et al., 2016). The number of statements collected from both researchers were then compared and discussed to resolve any discrepancies.

The final item analyzed was the observations from the researcher and the teachers. The researcher took notes during the lessons observing student interactions, while the teachers completed a questionnaire (found in Appendix D) after the week delivering the science lessons. The questionnaire focused on the teachers' observations regarding student science achievement and engagement.

Step 3: Coding Process

The coding process is a process of categorization, description, and synthesis. The researcher analyzed the transcripts and coded data that addressed the two research questions, comparing segments of data with each other within each interview transcript. The method used to organize the data was coding for categories (Merriam, 1998; Strauss & Corbin, 1998).

There are a number of different possible codes that may be used, and the coding categories should be specific to the research study (Merriam & Tisdell, 2016; Miles & Huberman, 1994; Wiersma & Jurs, 2005). With a basic interpretive qualitative research design, the research problem and the purpose of the research influence the type of coding system used. In this study, a general subject's perception coding system was used as described by Wiersma and Jurs (2005). The important characteristics of this coding system are that: "(1) the system accurately captures the information in the data relative to what is being coded, and (2) the information is useful in describing and understanding what is being studied" (p. 207).

In this study the following procedure was conducted for the coding process.

1. The recordings were initially reviewed.
2. The two research questions were set forth as foundational topics for the data, with emphasis on the student engagement question. Qualitative data provides critical insights to student's discussions and questions and gives a clearer picture of how engaged students are in the science lesson compared to quantitative data.
3. Quotes were identified to provide evidence that students were engaged and some general startup codes or keywords (e.g. claim, evidence, I agree, etc.) were identified from research (Nunez-Eddy et al., 2018, Zembal-Saul, 2009). During this process different startup keywords emerged from the participants. The carefully selected keywords that were identified included both content and skill based words and were arranged so that they fit within the research question (see Table 3.5).

Table 3.5. Keywords identified

Claim	**This evidence**	**I think this …**
Because …	**I agree …**	**I disagree …**
This is true …	**However …**	**What about …**
I observe …	**I predict …**	**This is different …**

4. Similarities and differences among the data were then identified, which led to sorting out the different keywords and creating appropriate categories. Bins, or descriptive categories, were created for which labels were devised to construct a conceptual scheme that suited the data. Using the key words, the data was then placed into one of the respective bins. Categories were created for each component of data that was collected. For example, student discourse questions from discourse analysis were put into three categories, procedural, supporting, and clarifying.

Step 4: Teacher Questionnaire

A questionnaire was developed after the quantitative data had been collected, analyzed, and interpreted. The questionnaire was designed to focus the teachers to reflect their observations of the students during the science instruction in relation to student achievement and engagement. Teacher observations from the questionnaire were compared with the researcher's observations of the students to provide two complimentary data points.

Comparison of the Two Phases

The benefit of a mixed methods study is the ability to compare and analyze both quantitative and qualitative data (Creswell & Clark, 2018). The explanatory sequential mixed method allows for first the quantitative data to help shape the way the qualitative data was analyzed and interpreted which in turn helps better understand the quantitative data (Burch & Heinrich, 2016). After the qualitative data was coded and analyzed, the study then went back to the quantitative findings to provide additional explanation and interpretation of the quantitative results. Figure 3 captures the approach used in the study.

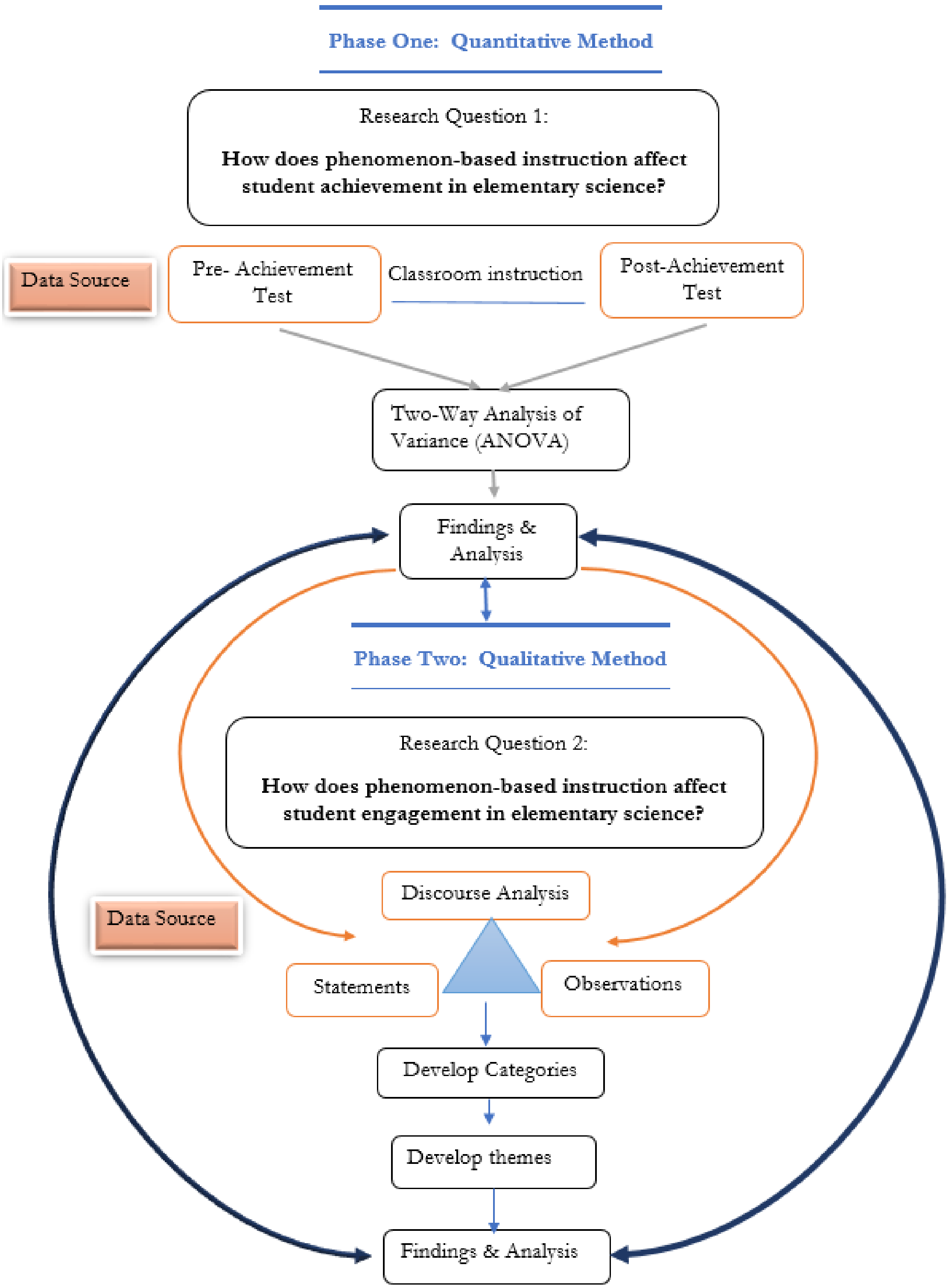

Figure 3. **Methodological Approach**

Subjectivity Statement

I was a classroom teacher and principal for twenty years and have been the science curriculum supervisor in the second largest school district in the state of Idaho for the last seven years. I have also been an active member in both the Idaho Science Teachers Association, NSTA, and the Idaho State Department Science Standards Committee. It is important I address my own subjectivity within this study. I have worked with thousands of teachers and pre-service teachers in science education. I have also had the opportunity to provide professional development on phenomenon-based teaching strategies throughout the state of Idaho the last four years and work in many teachers' classrooms modeling effective strategies to engage students in science. I would be remiss not to consider that the teachers working with in this study have had some knowledge of me as a science educator. As an insider (Dwyer & Buckle, 2009; Unluer, 2012), my responsibility as a researcher is to attempt to make the teachers chosen in this study feel comfortable delivering the lesson and not feel intimidated or evaluated by me as the observer. Having the role of science supervisor and professional development provider for the school district, I also have a bias to using phenomenon-based instruction in the classroom. To conduct credible insider research, I must constitute an explicit awareness of the possible effects of perceived bias on both the collection and analysis of the data (Smyth & Holian, 2008). One method for taking a preventive approach to credibility is the inclusion of a second external researcher to individually interpret data from the observation recordings. After both the external researcher and I interpreted classroom data from the recordings, both of us collaborated to determine similarities and patterns observed using the engagement instrument. The similarities is what is used in the results of this research. Because this data was interpreted by both of us, this helped with being an insider and showing that the results were discovered without bias.

Limitations

As in any research, a common concern is the limitations of the study, which identifies areas of weakness of the study (Castetter & Heisler, 1977). This study is no exception. Limitations of this study are:

1. Decreased generalizability due to the small sample size, four teachers who are teaching fifth grade, and the sample of participants all from one school district.
2. The teacher participants in the study volunteered to participate.
3. The data collected from test scores were limited to a pre and post assessment, observations, and statements made over the course of one month towards the beginning of the school year.
4. Conducting this research during the COVID - 19 pandemic caused some missing data. At one school, all students completed the pretest and participated in the first day of the instruction. Then a COVID outbreak took place the following day and five students out of the treatment group and two students out of the control group were quarantined for 10 days so their data was not included in the final analysis.
5. The time the science lessons were taught during the school day varied between groups. The schools could not change their daily schedules because of the block scheduling and tier intervention time, so each classroom taught science at a different time during the day. For example, at Sycamore elementary the control group taught the lesson in the morning (11:00 - 11:45) and the treatment group taught the lesson right before school was released for the day (2:30-3:15).

6. The study took place over a month period of time and the mini science lasted only a week in each classroom. It would strengthen the results if it could have taken place over a quarter or an entire unit of study.

CHAPTER FOUR: RESULTS

The purpose of this study is to determine the effects of using phenomenon-based instruction on elementary science achievement and student engagement. To answer the first research question, "How does phenomenon-based instruction affect student achievement in elementary science?" data were analyzed from a pretest and posttest centering on relevant physical science content and science skills. To help answer the second research question, "How does phenomenon-based instruction affect student engagement in elementary science?" three sources of data were collected, class recordings, statements made by the students, and the researcher's and teachers' observations.

The results from this explanatory sequential mixed method's study is broken into two sections in the order in which they were collected. First, the quantitative data findings from a two-way ANOVA from a pretest and posttest on science achievement on both factual and conceptual understanding is presented. The second section of this chapter presents the findings from the discourse analysis from recordings of students during classroom instruction, statements made by the participating students, and observations by the researcher and from the participating teachers.

Phase One: Student Achievement Findings

Findings of Student Achievement: Factual Knowledge

To evaluate the effect of phenomenon-based instruction on student achievement with factual science knowledge, a two-way ANOVA was used to examine differences across time (pretest versus posttest) and between groups treatment versus control). The ANOVA showed that performance on factual questions increased across time, F (1, 87) = 109.95, *MSe* = 1.20, $p < .001$, *partial eta squared* = .56, but that performance did not differ across groups, F (1, 87) < 1.0, *MSe* = 4.10, $p = .76$, *partial eta squared* = .01. There was a significant time by group interaction, F (1, 87) = 7.74, *MSe* = 1.20, $p < .01$, *partial eta squared* = .08, which indicates that gains from pretest to posttest were different for the two groups. Table 4.1 shows the results of the factual portion of the assessment.

Table 4.1. Mean performance (standard deviation) on factual test across time by group

Group	Pretest	Posttest	Gained Difference
Treatment n=44	4.25 (1.57)	6.43 (1.45)	2.18
Control n=45	4.80 (1.80)	6.07 (1.66)	1.27

To better understand the interaction, follow-up tests of simple effects were conducted. Performance increased significantly across the pretest and posttest for both the control group [F(1, 44) = 29.75, p < .001] and the treatment group [F(1, 43) = 87.83, p < .001], with gains greater for the treatment group than for the control group. On the eight multiple choice factual knowledge questions on the assessment (found in Appendix B), each question was worth one point with a total of eight points were possible on this portion of the test. Students in the control group improved by answering an average of one more question correctly from the pretest to posttest where students in the treatment group improved by answering an average of over two more questions correctly on the posttest.

In summary, the two-way ANOVA revealed that both the control and treatment group students increased in factual learning from the pretest to posttest. However, the treatment group students that received phenomenon-based instruction showed a statistically significantly higher improvement rate in factual learning achievement compared to the control group (See Figure 4).

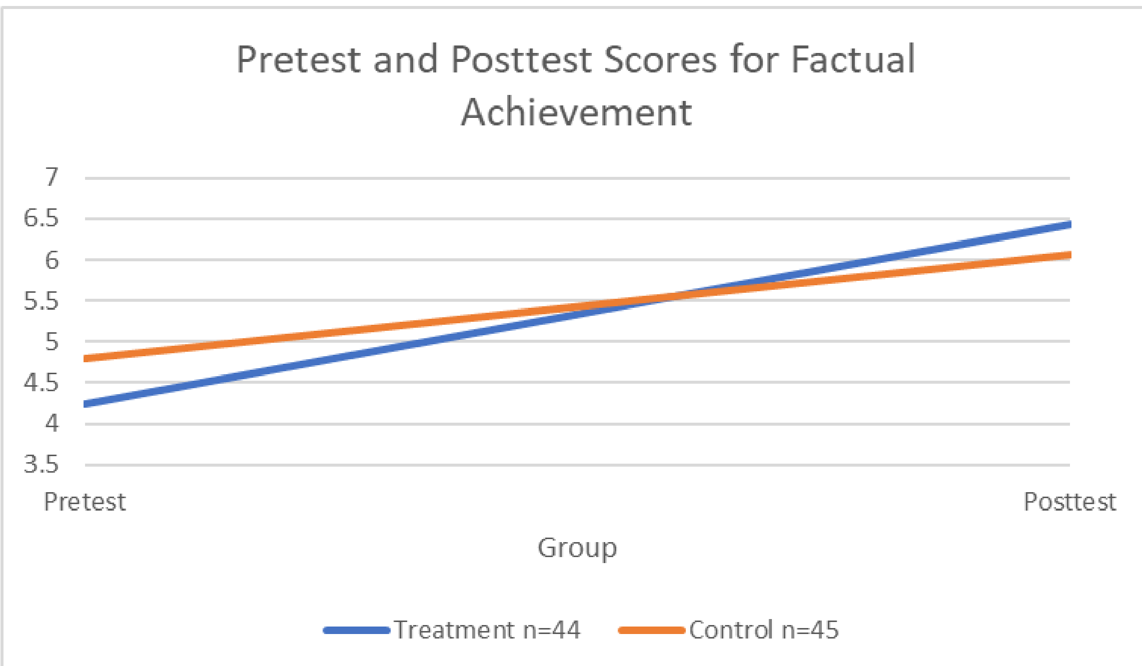

Figure 4. Pretest and Posttest Scores of Factual Achievement

Findings of Student Achievement: Conceptual Knowledge

The effect of phenomenon-based instruction on student achievement with conceptual science knowledge was evaluated with a two-way ANOVA test. A two-way ANOVA examines differences across time (pretest versus posttest) and between groups treatment versus control). The second part of the assessment contained two conceptual questions that focused not only on the physical science content that was presented during the unit but also science process skills such as argumentation. A rubric (Appendix C) was developed to score each of these two questions. The first question was given 0 to 3 points, while the second question was given 0 to 4 points. The two way ANOVA showed that performance increased across time, F (1, 87) = 31.15, MSe = 1.77, p < .001, *partial eta squared* = .26, but that performance did not differ across groups, F (1, 87) < 1.0, MSe = 5.02, p = .51, *partial eta squared* = .01. The interaction was not significant, F (1, 87) < 1, MSe = 1.77, p = .65, *partial eta squared* < .01. Thus, for the conceptual test, both groups increased performance across time and the groups increased performance at similar rates. Table 4.2 shows the results of the conceptual portion of the assessment.

Table 4.2. Mean performance (standard deviation) on conceptual test across time by group

Group	Pretest	Posttest	Gained Difference
Treatment n=44	3.89 (1.74)	5.09 (1.76)	1.2
Control n=45	4.20 (2.09)	5.22 (1.76)	1.02

Collectively, the short answer conceptual knowledge questions totaled seven points. Students in the control group improved by receiving an average of 1.02 more points from the pretest to posttest where students in the treatment group improved by receiving an average of over 1.2 more points correctly on the posttest.

In summary, the results demonstrate that both the control and treatment group showed an increase in conceptual learning. However, there was not a statistically significant difference between the growth of the pretest and posttest scores of the control and treatment groups on the two questions dealing with conceptual knowledge (see Figure 5).

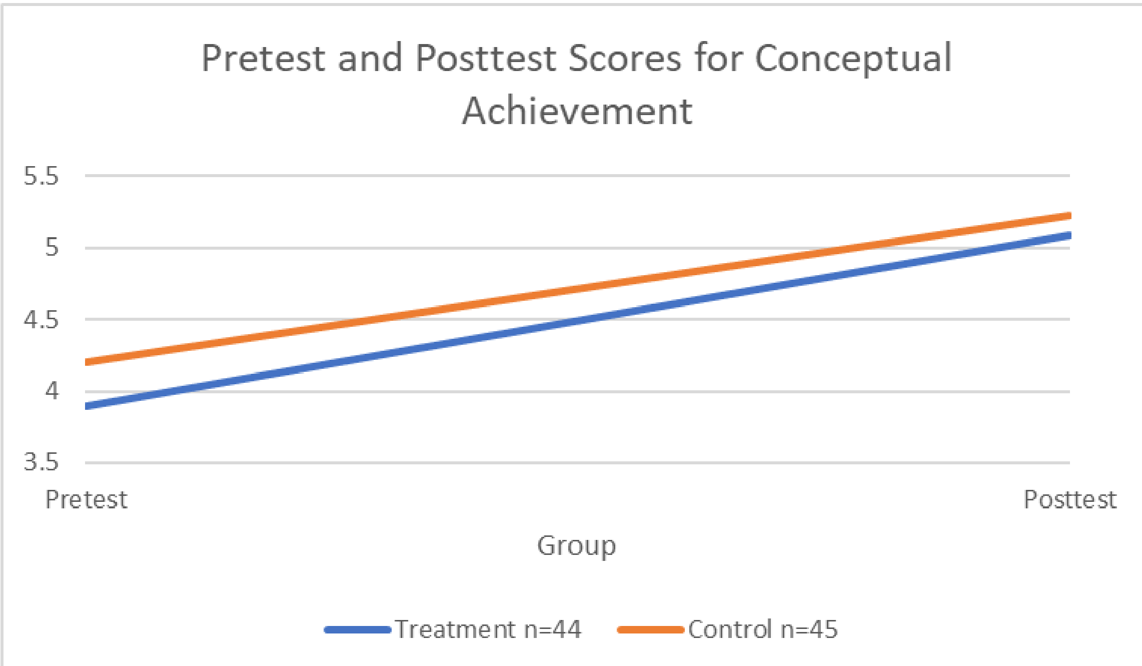

Figure 5. Pretest and Posttest Scores of Conceptual Achievement

The quantitative data reveals that phenomenon-based instruction has positive effects on student achievement. There is a strong correlation between using phenomenon-based instruction and students' factual knowledge, as the students in the treatment group scored over two points higher on their posttest as compared to their pretest. Conceptual knowledge of the treatment group did not show a statistically significant improvement compared to the control group; however, the students who received phenomenon-based instruction still scored over one point higher on their posttest. Phase Two of the findings looks at using qualitative data to build on the quantitative results of student achievement while also analyzing how students' engagement was impacted.

Phase Two: Student Engagement Findings

Phase One of the study shows there is a correlation between increased student achievement and phenomenon-based instruction. Students who received this type of instruction performed better than those that received traditional methods of instruction. The second research question explores whether phenomenon-based instruction positively affects student engagement similar to the findings related to student achievement.

In Phase Two, data were collected from three different sources: (1) discourse analysis from recordings of students' discussions during classroom instruction, (2) transcription of statements made by the participating students and (3) observations from the researcher and participating teachers. The qualitative data were used to measure elements related to phenomenon-based instruction to determine if this type of instruction affected student engagement. The first element is the extent to which students participated and communicated with fellow students on science related matters. This element is important because when students are talking with others about subject matter, they display higher levels of cognitive, behavioral, and emotional engagement (Fredricks et al., 2016). The second element is the extent to which students demonstrated science argumentation in their discourse. This is important because when students make a claim, they need to be able to either defend or disprove using evidence and thereby engage themselves more in science literacy (Probosari et al., 2017; Zembal-Saul, 2009). The final element measured is the extent to which students make sense of what they are learning in science and connect what they are learning to other applications outside of the classroom. When students build or revise explanations to figure something out, they are demonstrating sensemaking of both the science knowledge and skills that are learned in the classroom (Tannen, 1993). The findings of each of these elements are discussed in further detail.

Element 1: Participation with Others on Science Content

Participation in student discourse was measured through four different data points in this study. The first was the number of science related questions that were asked by the students. The second, was the type of science related questions asked by students. The third was the range of science related vocabulary used by students during discussions. The final metric was the observations made by the researcher and teachers.

Element 1.1. Number of Questions Asked

Engaging students in discourse or talking productively on the topic in an academic environment is at the heart of science education reforms as students are expected to participate in disciplinary discourse at more rigorous levels than ever before (Siayah et al., 2019). Having students ask questions about their learning generates excitement and engagement (Peterson & Eeds, 1990). When students are engaged, they have higher achievement scores (Crossan et al., 2003; King, 2015; Lei et al., 2018). Through the week of science lessons, students in both the control and treatment groups worked in small groups and were given opportunities to ask questions to other students. The number of student questions relating to the science curriculum that were heard in both small group and whole class settings were tallied. See Table 4.3.

Table 4.3. Number of total questions asked by students

	Ash Elem. Control Group (Mr. Smith)	Sycamore Elem. Control Group (Ms. Hawkes)	Total Control Group	Ash Elem. Treatment Group (Ms. Jones)	Sycamore Elem. Treatment Group (Ms. Wray)	Total Treatment Group
Day 1	9	11	20	14	13	27
Day 2	12	14	26	18	18	36
Day 3	14	8	22	30	27	57
Day 4	8	9	17	15	17	32
Total Questions Asked	**43**	**42**	**85**	**77**	**72**	**149**

The data showed three distinct findings based on the number of questions:

1) Students in the treatment groups overall asked 57% more questions (149) versus the control group (85). Students who were provided a phenomenon-based instruction also progressively asked more questions throughout the week while the control group questions decreased throughout the week.
2) Depending on the specific daily lesson that was taught, the number of questions varied. For example, day four of the lessons was mostly conducted through demonstrations by teachers on physical and chemical changes so the students had less time working in small groups and were not given as much of an opportunity to ask questions. In contrast, the activity on day three of the lessons, the students

spent most of the period inquiring about different materials and determining how to test for physical properties like magnetism, reflectivity and electrical conductivity. Because of the structure of this lesson, students had more opportunities to work and discuss with group members which led to more questions asked in both the control and treatment groups.

3) The qualitative data show that the quantity of questions was consistent between the control classrooms. The two control groups asked approximately the same number of questions throughout the week, Ash Elementary with 43 questions and Sycamore Elementary with 42 questions. The number of questions between the control group also mirrored throughout the week, but the number of questions asked did decrease overall by day 3. The same findings were true for the treatment groups, Ash with 77 questions and Sycamore with 72 questions. However, in the treatment groups, the number of questions asked increased dramatically during day 3. The findings for both show that two different schools had very similar results.

Element 1.2 Type of Science Questions Asked by Students

Deep learning by students is made possible by providing time for high-quality discourse, which allows students to ask questions to help promote engagement and a more meaningful understanding of the content (Fisher et al., 2020; Klem & Connell, 2004). Both the control and treatment group followed the same structure of lessons and the teachers gave students the opportunity to work together in small groups. Many types of questions were similar in both the control and treatment group, but there were also a few differences. Three types of questions were identified: (1) Procedural: focusing on asking procedural questions about the science activity, (2) Supporting: asking others in their group for support/help on specific science tasks, and (3) Clarifying: clarifying questions about the science content. Table 4.4 identifies a small sample of the questions by theme asked by students in both the control and treatment groups.

Table 4.4. Types of questions asked by students

Themes	Control Groups	Treatment Groups
Procedural	- How do you get the light bulb to work? - Which powder do we add the water to next? - How do we use the laser?	- How does this light? - How do we mix the white powders in water? - What do you want to test first?
Supporting	- Can you show me how to hold the wire? - Where is the water?	- How do you use the wire to make the light bulb go? - Should we add baking soda or baking powder?
Clarifying	- Which way do you think they sorted them (rocks)? - Wow, how is the spoon lighting the bulb? - What is different about the powder?	- Why do you think they sorted them by texture? - How does the laser show us reflectivity? - Why doesn't the wood catch on fire when doing the conductivity test? - What do you think is in the (inflating) balloon to make it get bigger?

The data showed two findings based on the type of questions asked:

1) In the themes of procedural and supporting questions there was little to no difference on the types of questions asked between the control and treatment groups. The students in all four classrooms asked very similar types of questions. For example, both control and treatment students asked questions concerning how to light the bulb, how to use the wire and battery to activate the bulb, and how to mix different white powders.
2) Although there were similar types of questions asked, the treatment group asked more clarifying questions. These questions were open-ended questions that allowed for more discourse to transpire than in the control group. The students in the treatment group also asked more clarifying questions that connected back to the phenomenon being studied. For example, a student in Ms. Wray's treatment group at Sycamore asked the question, "What do you think is in the inflating balloons [the phenomenon] to make them get bigger?" This type of question sparked a conversation with the other students in the group as to what was in the self-inflating balloons since none of the students knew exactly how the balloon expanded by itself. This type of clarifying question engaged the students in the topic, which led to one of the students in the group mixing both baking powder and baking soda with water to show a chemical change that created a gas to help answer this question. This shows that this group of students are actively "drawn in" to ask questions, wonder, and have engaging discourse with their peers to determine the explanation of what causes the phenomenon (Mancuso, 2017).

Clarifying questions asked by students can encourage dialogue and promote the establishment of shared meaning or common knowledge in the classroom.

Element 1.3 Number of Physical Science Vocabulary Vocalized by Students

Students show a better understanding of the science content when using science vocabulary in their discourse (Kennedy et al., 2017; Rupley & Slough, 2010). Recording the number of science terms verbalized by students shows that the students are actively participating in the content, staying engaged, and staying on topic during small group discussions. Nine specific physical science words were identified by the researcher as important to support in the learning of content and also because these are the words tested on the factual content portion of the pretest and posttest. See Table 4.5.

Table 4.5. Science vocabulary identified

Properties	Texture	States of Matter
Reflectivity	Magnetic	Conductivity
Physical Change	Chemical Change	Dissolved

To collect data on students using specific science vocabulary words, both researchers listened to student recordings from iPads. The number of times students used one of the nine physical science vocabulary words in both small group and whole class settings were tallied. The data findings are presented in Table 4.6.

Table 4.6. Number of science vocabulary used by students during the week

	Ash Elem. Control Group (Mr. Smith)	Sycamore Elem. Control Group (Ms. Hawkes)	Total Control Group	Ash Elem. Treatment Group (Ms. Jones)	Sycamore Elem. Treatment Group (Ms. Wray)	Total Treatment Group
Properties	9	11	20	7	5	12
Texture	14	11	25	20	19	39
States of Matter	8	8	16	12	17	29
Reflectivity	19	25	44	33	30	63
Magnetic	25	24	49	29	24	53
Conductive	28	19	47	25	27	52
Physical Change	18	22	40	26	30	56
Chemical Change	19	25	44	25	24	49
Dissolved	14	10	24	17	16	33
Total	**140**	**155**	**295**	**194**	**192**	**386**

The data showed two findings relating to the number of times specific science vocabulary or a derivative was used:

1) Students in the treatment group used the physical science vocabulary at a higher rate. At Ash Elementary students in the treatment group used the words 28% more than the control group. At Sycamore Elementary students in the treatment group used the words 20% more than the control group. There were 90 more instances of the science words in the combined treatment groups over the control groups.
2) Some vocabulary words were used more frequently than others due to the hands-on activities the students participated during the lesson. For example, on day three, both the control and treatment students were involved in an inquiry activity where they had to determine if certain objects (e.g. nail, foil, and plastic spoon) demonstrated properties of reflectivity, magnetism, and conductivity. As observed in the data, these three science vocabulary words were used over 40% more often than the other property vocabulary words like texture and states of matter.

<u>Element 1.4 Observations of Researcher and Teachers on Participation</u>

There were numerous observations by both the researcher and the teachers regarding student participation with others on the science content. When asked about components of the lessons that helped engage students, the treatment group teachers focused on discourse. Ms. Jones, the treatment group teacher at Ash Elementary, said "I really liked how the class in both small groups and the whole class brainstormed to open the conversation. This helped build some basic understanding and connected prior knowledge among the whole group before diving into the activity." Ms. Wray, the treatment group teacher at Sycamore Elementary, mentioned "The phenomenon! Wow this truly hooked the student in the lesson and got them talking and wondering about science. They were so eager and curious to learn what was next and their minds were racing like little scientists." Both teachers observed that the students engaged with their fellow students on the subject matter as they were using the science vocabulary and questioning one another. The researcher's own observations mirrored what both teachers observed. The researcher observed students talking to each other and asking many "why" questions that created students being engaged. Students felt comfortable asking questions while other members of their team actively listened and pressed more conversation. For example, a student in Ms. Wray's classroom asked "Why doesn't the wood catch on fire when doing the conductivity test?" A fellow student made a connection and stated that this is why many homes are built with wood because wood is not a conductor. Another student pressed the group by asking why you should not stand under a tree during a lightning storm if wood is not a conductor. This conversation continued for a couple of minutes, all stimulating from the original student's question.

The teachers in the control group focused on the actual activity as the focus of the engagement rather than the questions and vocabulary. Ms. Hawkes, control group teacher at Sycamore, said "The hands-on activities engaged students and made them think and ask questions about science." Mr. Smith, control group at Ash Elementary, said "The lessons were quick and engaging through the entire process. The materials used engaged the students to explore and work together." The researcher observed students talking in the control groups, but many times the talk was not related to the activity and few deep-thought questions were asked. For example, a student in Ms. Hawkes' class asked his group "What do we use the laser for?" Another student in his group answered, "Look how the laser looks on my hand." The original question, being a low-level question, did not spark the interest of other students in his group or make them use any science vocabulary to participate in an in-depth discussion.

In summary, participating with others on science content by asking more high-quality questions as well as using more scientific vocabulary words in discourse can lead to student engagement. Using Fredricks et al. (2016) engagement framework, students in the treatment group demonstrated behavioral, emotional, and cognitive engagement by extensive participation in discourse. The data show that behavioral engagement was promoted by the treatment groups through students being involved in the activities and asking more questions that focused specifically on the science they were learning (Buhs & Ladd, 2001). Emotional engagement was achieved by the treatment students interacting with others while building an understanding of the science content and vocabulary while being actively involved in the science learning (Reyes et al., 2012). Cognitive engagement was accomplished by the treatment students asking more complex questions through discourse that help promote more conversations and motivate them into a deeper understanding of the science content (Corno & Mandinach, 1983). All three types of engagement were achieved by the treatment students through participating with others through discourse.

Element 2: Demonstrating Science Argumentation

Argumentation has been signaled out as an important discourse component in science learning and engagement (Ghousseni et al., 2015). Argumentation is defined as the process of justification by which evidence and reasoning is used to support or explain a scientific claim (Berland & Reiser, 2009). In the real world, scientists spend a great deal of time assessing, critiquing, and defending the evidence that they use to support or challenge a claim (Zembal-Saul, 2009). Incorporating scientific argumentation in the classroom is important because we want students to participate and engage in practices like scientists.

Students making claims with evidence were measured through three different data points. The first was the tallying the number of times students demonstrated argumentation by making claims and/or providing evidence. The second, was the type of argumentation demonstrated by students through their statements. The final metric was the observations made by the researcher and teachers.

Element 2.1. Number of times students demonstrated argumentation

Through discourse, students can elaborate on and justify their reasoning. Justification, especially justifying claims-evidence relations, is an important part of argumentation (McNeil et al., 2006). Students that engage in the scientific discourse of proposing and arguing about ideas show a better understanding of the science concepts taught (Mancuso, 2017). Phenomenon-based instruction drives the class to present claims, defend their own claims, and rebut the claims of others that they disagree with while using evidence (Driver et al., 2000). Through the week of science lessons, students in both the control and treatment groups worked in small groups and were given opportunities to justify using argumentation. To collect the data on student argumentation, student recordings from iPads that were placed in the middle of the small groups of students were listened to by both researchers. The number of times students demonstrated argumentation by using evidence to support or disprove a claim, either their own claim or someone else's claim in the classroom were tallied. Through the coding process a number of keywords and phrases were identified that supported the concept of argumentation. The keywords and phrases were chosen from research on engaging elementary students in argumentation (Nunez-Eddy et al., 2018; Zembal-Saul, 2009) and also the words commonly used by both the control and treatment students in the study. Those keywords and phrases are identified in Table 4.7.

Table 4.7. Keywords and phrases supporting argumentation

I think this	Because	I agree	I disagree
This is true	However	What about	This evidence

Keywords identified through the coding process were listened for in the recordings. The students used these keywords and phrases throughout the science week. It varied depending on the day, but overall, the treatment group used the words and phrases more than the control group. For example, Jimmy in Ms. Jones's treatment group at Ash Element said, "*I think* the baking soda is going to explode when vinegar is added." Bridget in Mr. Smith's control group at Ash said, "*because the* vinegar will react with baking soda causing it to explode." Table 4.8 shows the number of times students used argumentation during the science week.

Table 4.8. Number of times students used argumentation strategies

	Ash Elem. Control Group (Mr. Smith)	Sycamore Elem. Control Group (Ms. Hawkes)	Total Control Group	Ash Elem. Treatment Group (Ms. Jones)	Sycamore Elem. Treatment Group (Ms. Wray)	Total Treatment Group
Day 1	1	0	1	2	2	4
Day 2	3	5	8	8	10	18
Day 3	7	8	15	10	11	21
Day 4	5	5	10	14	13	27
Total	**16**	**18**	**34**	**34**	**36**	**70**

The data showed three findings relating to the number of times students demonstrated argumentation:

1) Students who were provided phenomenon-based instruction overall used more argumentation during discourse. The total number of argumentation strategies asked by the treatment group compared to the control was 50%. Students who were provided phenomenon-based instruction progressively demonstrated argumentation throughout the week starting with an average of 2 times demonstrating argumentation during the first lesson and 13 times during the fourth lesson.
2) Depending on the specific daily lesson that was taught, the number of argumentations varied. For example, day four of the lessons were focused on

determining through demonstrations and an investigation which type of change, physical or chemical, was occurring. Students had an opportunity to demonstrate argumentation more on this day because during student discourse they were trying to prove to their partners the type of change they believed occurred and through providing evidence why they believed this.

3) As the week progressed, the treatment group consistently used argumentation more often compared to the control group that showed a decrease on day 4.

Element 2.2. Type of argumentation demonstrated

Using augmentation through student discourse drives the class to present claims, defend their ideas, and rebut the claims of others that they disagree with while using evidence (Driver et al., 2000). Lehrer and Schauble (2007) summarized that science must be examined, not only in terms of a product - such as students' understanding of scientific accurate explanations - but also in terms of the ways students talk and argue about phenomena within a community of practice. Argumentation in elementary science consists of students stating what they believe to be true through a claim and then defending it with evidence (Zembal-Saul, 2009). Other students can then agree with that student’s claim or use evidence to rebut the claim. Three key themes emerged from argumentation from students: (1) Making Claims: students stating what they believe to be true. (2) Defining Evidence: students giving specific facts or data from either the investigation, readings/videos or prior knowledge that supports their claim. (3) Using Reasoning: students explain why the evidence supports their claims. Table 4.9 identifies a small sample of the argumentation demonstrated by theme in both the control and treatment groups.

Table 4.9. Argumentation statements by students

Themes	Control Groups	Treatment Groups
Making Claims	- They sorted these rocks by shape - This is not flour - I believe it is a physical change	- I really think these are by texture … - This has to be a type of salt … - I agree with Ben, it is a chemical change …
Defining Evidence	- see they are from small to big. - it does not make a glob - because it can go back to its first shape	- this has to be texture because this group is rough and this group is smooth. - because it has similar properties like crystals and it dissolve - it can't turn back into a banana you can eat, so it has to be chemical
Using Reasoning	- Rocks are made by putting them with different color because this group is reddish. - Mr. Smith ripped the paper so that has to be physical; it is still paper.	- I disagree it does not look like texture but size; this pile is tiny and this one is bigger rocks. - Physical changes are like the ice in water but the banana is like the paper being burned - can't go back to its start.

The data showed two findings based on the type of argumentation used:

1) Both the control and treatment group students had similar claims, stating what they believed to be true in the different investigations and demonstrations. The activity being explored by students in the classroom helped construct their claim.

2) The treatment groups used science vocabulary and connected their evidence and reasoning back to the phenomenon much more often than the control groups. For example, Lucy in Ms. Jones' treatment class, defended her claim that the rocks from lesson one were sorted by texture by describing how the rocks were both smooth and rough and the rough rocks were similar to the mystery rock shown by Ms. Jones at the beginning of the lesson. Lucy used science vocabulary, texture, and connected back to the original phenomenon showing she was connecting her argumentation to a prior experience. Another example, Levi in Ms. Wray's treatment class gave evidence on the mystery powder by saying; "I think it is salt. It has properties like crystals and dissolves, plus it feels like salt!" Again, using science vocabulary words like properties, crystals, and dissolves demonstrates a better understanding of the content and shows a connection focusing on specific phenomena (Lehrer & Schauble, 2007).

The control group demonstrated evidence and reasoning, but most of their examples recorded focused on a quick explanation of why something happened instead of embedding evidence using science vocabulary to illustrate their understanding. Because of this type of argumentation, other students in the group did not respond with follow up questions or evidence to either support or contradict the original claim. For example, Beth in Ms. Hawkes' control class explained that the rocks were sorted by color in lesson one. She only gave one piece of evidence from one of the rock groupings by saying "Rocks are made by putting them with different color because this group is reddish." No conversation from the other students in her group continued about this topic after Sue's claim with evidence was made. Another example is Sue in Mr. Smith's control class used a teacher demonstration to explain it was a physical change. Sue stated, "Mr. Smith ripped the paper and it is still paper." The evidence did not use any science vocabulary or expand on her reasoning so again no other students responded to this claim. A similar claim made by Matt in Ms. Wray's treatment class shows how expanding on reasoning and attaching it to a phenomena can spark other students to respond and encourage argumentation. Matt explains that a rotting banana is a chemical change and says, "Physical changes are like the ice (melting) in water, but the banana is like paper being burned - can't go back to its start." Matt actually gives two examples of why the rotting banana phenomenon is a chemical change and the other students in his group agreed but also expanded using one of their examples of chemical changes - paper burning. This practice shows a high level of engagement because students can openly discuss and decide for themselves among different claims and perspectives of the same phenomenon.

Element 2.3. Observations of Researcher and Teacher on Argumentation

There were many observations by both the researcher and the teachers regarding student argumentation. When asked about what in the lessons supported students making claims with evidence, the control group teachers focused on how the students used discourse while the treatment group teachers focused on students using evidence while explaining their reasoning. Ms. Wray, treatment teacher from Sycamore Elementary, stated "the discourse at the tables was so nice to hear, especially how they applied the scientific vocabulary in some of the conversations. I honestly felt the students were talking like scientists explaining their evidence!" Ms. Hawkes, control teacher from

Sycamore Elementary, took a different approach to the question by saying “I noticed students having conversations while trying to figure out problems and experiments. The students were active and cooperative.” The researchers' observations were similar. The treatment group students were demonstrating good argumentation by going back and forth in their discourse and providing evidence to support their thoughts. One example from Ms. Wray’s classroom was a small group of students conducting a good argumentative conversation about what was inside the self-inflating balloons. Sally started by saying “I think it is baking powder and water in the balloon to make it inflate because those make a gas when they are mixed.” Ramon then countered “I agree it has to be a chemical reaction, but it has to be bigger than just baking powder.” Lilly responded by saying “well remember the balloon felt cold, I don’t remember if the baking powder and water was cold.” The students in this group then all agreed they should go test putting baking powder and water together again to see if it turns cold. The conversation continued and more argumentation occurred as students investigated, used evidence, and showed curiosity by wondering what was inside the balloon to make it self-inflate. By emphasizing argumentation within a phenomenon, students develop both cognitive and behavioral engagement (Engle & Conant, 2002). Because of this, engagement can be viewed in terms of discourse practices that extend beyond just the behavior of individual students and instead involves the social interaction of a group of students.

In summary, students demonstrating argumentation in the classroom can lead to student engagement (Cappella et al., 2013; Fredricks et al., 2004). Argumentation has been singled out by researchers to be an important component of student discourse which leads to engagement (Ghousseni et al., 2015; Michaels, et al., 2008; Zembal-Saul, 2009).

The treatment group students demonstrated argumentation by making claims while providing evidence during student discourse. The treatment students also contributed to the learning process by connecting more science vocabulary to their evidence. The data shows the treatment students demonstrated argumentation skills by going back and forth in their discourse while performing science tasks that contributed to their evidence and reasoning.

Element 3: Demonstrating Sensemaking of the Science Content

Sensemaking is a form of reasoning that requires students to act on ideas generated from investigations, other students' claims, and from one's own base of knowledge and experience (Cannady et al., 2019; Kapon, 2017). Sensemaking is a conceptual process in which a learner engages with the phenomena, wonders and asks questions about it, and then develops, tests, and refines their ideas to make meaning (National Center for Educational Statistics [NCES], 2021). By making sense of the science students can apply what they have learned to other situations outside of the classroom. In this study, students making sense of the content was measured through two different methods. The first was looking for statements' students articulated while attempting to make sense of the science content being taught. The second was the observations made by the researcher and teachers.

Element 3.1. Sensemaking statements by students

Researchers believe sensemaking needs to be a part of elementary science classrooms because: (1) sensemaking promotes student engagement and "deep" learning which allows students to actively build connections between new and existing knowledge while encouraging interest in the topic (Chin & Brown, 2000; Danielak et al., 2014) (2) making sense of ideas facilitates the process of transferring ideas to new and different topics and circumstances (Kapon, 2017; Ruibal-Villasenor et al., 2007).

Two key themes emerged from the audio recordings related to sensemaking: connections and applications. The connections theme is when students link their idea to the initial investigation or a phenomenon. The applications theme is when students used a science concept and applied it to a situation outside of the classroom instruction. Table 4.10 identifies a sample of sensemaking statements demonstrated by both the control and treatment group students.

Table 4.10. Sensemaking statements by students

Themes	Control Groups	Treatment Groups
Connections	- This is like the Oobleck in 2nd grade. - I have a rock collection at home that is similar to this rock - The flour and water are like dough for cookies - That chunked up like cottage cheese, gross!	- I put baking soda and water in a bottle with a lid and it exploded. - The goo is magnetic, I wonder if it will conduct electricity since it has iron - The mystery goo reminds me of Venom, it stretches and moves - I wonder if he is magnetic. - My berries rotted like that banana!
Application		- Does water have reflectivity because I can sometimes see my face when I look in it - Houses are built out of wood because they aren't conductive and won't catch on fire - If wood isn't a conductor, why are you not supposed to stand next to a tree during a lightning storm at school - I wonder if life rafts inflate like the balloons

The data showed two findings based on the sensemaking demonstrated by students:

1) Both the control and treatment group students made connections from the activities or phenomenon to something in their life. The treatment students

connected frequently to phenomena that were presented like the magnetic goo, the mystery rock, self-inflating balloons, and the rotten banana. Since the control group did not have phenomena presented in their lessons, the students had only the actual science investigations to connect too. The control group had also made fewer connections than the treatment group.

2) There were no applications of the science content to the real world observed in the control group. However, the treatment group made four applications from the science content to the outside world (all listed in Table 4.10). Three of the four applications came directly from one of the science investigations during the week, while the fourth application was illustrated from one of the phenomena.

Element 3.2. Observations of researcher and teacher on sensemaking

The teachers were not asked a specific question about sensemaking; however, the treatment teachers did talk about how the phenomena was a gateway to students making connections. Ms. Jones stated, "One of the components that engaged the students the most was the phenomena. It led to questions, ideas and conversations and I was impressed with how they connected what we were learning back to the phenomenon." Ms. Wray added, "Every student's engagement was high! I noticed that my students were having deeper level conversations and making real-world connections with the activities and phenomenon. I was especially pleased with how they started to make connections and really saw the difference between physical and chemical changes." The researcher noticed that the connections and applications developed by students were shared to others which built a better understanding for everyone in the group. Having students share connections increases students' engagement on the science content (Erduran et al., 2004).

The teachers in the control groups mentioned nothing about student connections, but did mention how the students gained a shared understanding. Mr. Smith said "Coming from a project-based background, I would say the hands-on elements of the lessons helped bring the students together to help build their knowledge together." Ms. Hawkes mentioned, "The science was so fun and I love seeing students work together while doing experiments. I felt they built a strong connection going through the same activity." The researcher observed the treatment group having many more authentic discussions that led to connections and in turn allowed for more discourse to happen in the groups compared to the control group students.

Summary of Findings

The first research question asked how phenomenon-based instruction affects student achievement. The findings showed that phenomenon-based instruction positively impacted student achievement in terms of both factual and conceptual knowledge. The treatment group demonstrated statistically significant improvement on their factual knowledge compared to the control group students while both groups demonstrated similar improvement on their conceptual knowledge understanding.

The second research question asked how phenomenon-based instruction affects student engagement. The findings showed phenomenon-based instruction affects all three aspects of student engagement, behavioral, emotional, and cognitive (Fredricks et al., 2004). The treatment group students demonstrated engagement by participating in more discourse opportunities, having more argumentation-based discussions with each other, and by using sensemaking skills to make connections of the science content presented. The treatment students not only asked more questions, but also used more scientific vocabulary words in their discourse and evidence statements. The treatment students also had more incidents of argumentation and sensemaking during the week. In the final chapter, specific interpretations of these findings as well as recommendations for future research will be discussed looking at the results.

CHAPTER FIVE: DISCUSSION AND CONCLUSION

High quality elementary science instruction, like phenomenon-based instruction, engages students to ask more questions, wonder about the natural world around them, and work with others to make sense of the science content while connecting their learning to real-world situations. Elementary students who learn to think like scientists not only learn more science facts and concepts, but also increase their engagement and motivation to practice higher level thinking skills while building science literacy (Cannady et al., 2019; Edwards & Mercer, 2013). Using phenomenon-based instruction, teachers can guide students toward the development of knowledge and skills in science as well as their excitement in learning science by providing opportunities for students to construct their own knowledge by using relevant phenomena (Mancuso, 2017).

The purpose of this mixed methods study was to determine the affects of phenomenon-based instruction on elementary student's science achievement and engagement in the classroom. This study builds upon existing research related to using phenomena-based instruction in the classroom and makes new contributions to the field, especially in elementary science education research where there are very few existing studies. The focus of this chapter is to interpret the study results and present the interpretation in alignment with the two research questions presented in Chapter One. First the chapter briefly summarizes key findings of the study. Next, the findings will be interpreted to help better understand the quantitative data as well as the qualitative results. Finally, the chapter presents recommendations for further research in the area of phenomenon-based learning.

Summary of Key Findings

The first research question posed was, “How does phenomenon-based instruction affect student achievement in elementary science?” Student achievement was measured for factual knowledge and conceptual knowledge acquisition. The factual knowledge analysis showed that even though both the control and treatment group increased in factual learning, the treatment group students improved statistically significantly higher on the posttest compared to the control group. The conceptual knowledge analysis showed that both the control and treatment groups improved from pretest to posttest. There was, however, no statistically significant difference between the two groups regarding conceptual knowledge acquisition.

The second research question posed, “How does phenomenon-based instruction affect student engagement in elementary science?” Student engagement data was collected by: discourse analysis from recordings of students’ discussions during classroom instruction, transcription of statements made by the participating students and observations from the researcher and participating teachers. The results were then analyzed through three elements; (1) participation with others, (2) demonstrating argumentation, and (3) exhibiting sensemaking. The analysis showed students taught using phenomenon-based instruction demonstrated higher engagement during the science lessons.

The first element examined, participating with others, showed that students in the treatment group not only asked over 50% more questions, but they also used over 25%

more science vocabulary in conversations. The treatment students also asked more open-ended clarifying questions that promoted more student to student discussions during the science lessons. When students communicated about the science content with one another, it allowed and extended the process of exploration and discovery, which is the essence of science (Fisher et. al, 2020). Phenomenon-based instruction supports opportunities for student discourse and students are prompted to ask and answer their questions which empower them to share their ideas with others. Participating in discourse using phenomena also provides students' opportunities to explore ideas and piques curiosity of the relevant science concepts being learned (Herrenkohl & Guerra, 1998; Newman, 1986).

The second element investigated, students demonstrating science argumentation, showed the treatment groups participated in argumentative discussions over 50% more than the control group. They also produced more conversations that connected evidence and reasoning to phenomena which led to rich discussions that prompted students using more scientific vocabulary and evidence to support their claims.

The third element analyzed, exhibiting sensemaking, showed both the control and treatment groups making connections to what they were learning, however only the treatment group provided real-world applications in their discussions. Interpretations of all these elements will be explained in more detail in the interpretation of findings.

Overall, this mixed methods study showed that phenomenon-based instruction positively affected both student achievement and student engagement. Compared to traditional science instruction seen in many elementary science classrooms, phenomenon-based instruction engaged students in discourse, argumentation, and sensemaking while providing higher achievement in the science content.

Interpretations of Findings

Research and literature have shown elementary science instruction across the country is not improving and many elementary schools are either teaching using traditional methods or not providing ample time for students to ask questions, practice argumentation skills, or make connections in science (Banilower, 2019; Blank, 2013; Judson, 2013: Rosenshine, 2015). The results of this study reveals that there is an instructional pedagogy - phenomenon-based instruction - that not only can improve student science achievement, but also increase student engagement. Interpretations for both research questions are addressed in detail.

<u>Research Question 1: How does phenomenon-based instruction affect student achievement in elementary science?</u>

The first research question sought to determine if phenomenon-based instruction affects student achievement in elementary science. The data collected from pretest achievement scores and posttest achievement scores was analyzed by a two-way ANOVA on both factual and conceptual knowledge acquisition.

The results on the factual knowledge showed a significant statistical difference between the treatment and control groups. Students who received phenomenon-based instruction answered more than one more factual multiple choice question correctly on the posttest compared to the control group. One reason for this result could be that students were better able to build background knowledge in the science content through the presentation of a phenomenon. The treatment group had opportunities to connect the phenomenon to the content taught during the lesson, thus fostering sensemaking. Phenomenon-based instruction gives students an opportunity to build on their prior knowledge by engaging in discourse while allowing all students a common experience to discuss (Mancuso, 2017).

Another possible reason for the higher factual test results is the treatment group engaged in asking double the amount of questions during the week of instruction and used more scientific vocabulary in their discussions. Since each factual question on the posttest contained at least one physical science vocabulary word, the treatment students demonstrated active questioning and discussing their learning while using science vocabulary. This was specifically exhibited by the treatment group using more science vocabulary in their discussions compared to the control group. Practicing the science words over and over again during conversations helped students solidify the meaning and understanding of these words at a higher rate. Students who use science vocabulary more often while building understanding through conversation and exploration has indeed been shown to impact student achievement (Rupley & Slough, 2010; Young, 2005). These results convey that phenomenon-based instruction can support teachers in their science instruction to improve students' factual science content knowledge. Many elementary teachers worry that students will not learn factual content without direct instruction and lecture (Morgan et al., 2016), however, the data in this study indicate that this is not the case and by providing students more opportunities with phenomenon and discourse students perform better on factual science assessments.

The results of the conceptual understanding assessment, where students grasp ideas in a transferable way (Michaels et al., 2008), showed that both the treatment and control groups had comparable improvements from the pretest to the posttest. The findings concluded that there was not a statistically significant difference between the two groups. An example of one of the conceptual questions assessed on the posttest provided students with an example of a chemical change in matter that was not experienced during the week. The students then were asked to identify three things: a) the type of change (physical or chemical) they believed to have occurred b) provide at least two pieces of evidence that supports their claim and c) explain their reasoning using science vocabulary that connects their evidence to their claim. Over 85% of both the control and treatment students were able to identify correctly that the example provided was a chemical change. Most of these students were also able to give at least one piece of evidence, however both groups struggled being able to transfer their conceptual understanding to other situations while providing reasoning to support their claim. This may be due to the fact that students had only one week of science instruction to develop conceptual understanding of the physical science concepts taught. With a total of only five science lessons taught in the study, students may not have had an opportunity to deeply build reasoning and conceptual knowledge skills. For elementary students, conceptual learning takes time and requires multiple opportunities to make connections through observing, experimenting, and discussing with others in the classroom (Chen et al., 2013; Simsek &Kabapinar, 2010).

The treatment group students did, however, provide more responses that connected back to phenomena and showed the beginnings of conceptual understanding. One example introduced in the findings demonstrates this point. The conversation in Ms. Wray's treatment group classroom demonstrated the transfer of knowledge from one situation to another. One student started a conversation by making a claim on how the self-inflating balloon works. The student said, “I think it is baking powder and water in the balloon to make it inflate, because those make a gas when they are mixed.” A second student responded by saying, “Well the balloon felt cold, but I don’t remember [in an early activity students conducted] if the baking powder when mixed with water was cold.” This application of what the students already explored in the mixing powder lesson to a new situation two days later is an example of developing conceptual knowledge. Allowing students more time and practice in conceptual understanding through discourse, writing, and extending exploration opportunities for applying new ideas to a wide variety of problems may have supported students in better demonstrating their conceptual understanding on the assessment (Carey, 1999; White, 1993).

In summary, the results from the two-way ANOVA revealed that students who received phenomenon-based instruction achieved higher on factual knowledge questions compared to students who received traditional instruction, but improved similarly on conceptual knowledge questions. Based on these findings a qualitative design was next implemented to explore reasons why treatment group students' factual knowledge increased statistically significantly and why conceptual knowledge increased at similar rates between the treatment and control groups. The qualitative design was also used to determine students’ engagement during the science lessons. The qualitative research employed data from sound recordings of discourse between students, specific student statements during science lessons, and observations from the researcher and teachers. Key words, phrases, and student statements were coded and analyzed to determine if students who received phenomenon-based instruction were more engaged. The qualitative data attempted to answer the question, if students were more engaged, was this a primary factor that led to higher achievement scores on the posttest assessment?

Research Question 2: How does phenomenon-based instruction affect student engagement in elementary science?

The second research question was analyzed through a basic interpretive qualitative design and investigated through the triangulation of student discourse, student statements, and observations. The findings showed that phenomenon-based instruction positively impacted student engagement in three areas: (1) increased participation with others on science content, (2) increased engagement in science argumentation skills, and (3) exhibiting sensemaking of science content.

1) Students participating with others on science content

The findings showed that treatment students participated with others during science instruction by asking double the amount of questions, asking more in-depth clarifying questions, and using 28% more scientific vocabulary in their discussions compared to the control group students. Engaging students in discourse or talking productively on the topic in an academic environment is at the heart of science education reform as students are expected to participate in disciplinary discourse at more rigorous levels than ever before (Siayah et al., 2019). Having students ask questions about their learning generates excitement and engagement (Peterson & Eeds, 1990). Another added benefit is when students are more engaged in discourse between other students, they have higher achievement scores (Crossan et al., 2003; King, 2015; Lei et al., 2018). Using phenomenon-based instruction helped engage students in discourse by providing real-world phenomena in which students could openly explore and then discuss with others like scientists while using proper science vocabulary. The control group was not provided a phenomenon and, in turn, asked fewer questions, used science vocabulary at a lower rate, and did not engage in high-quality discussions as frequently as the treatment group. As Fredricks et al. (2004) affirms, students who actively participate in a lesson are more engaged, which correlates to higher achievement. This is a likely contributing factor to why the treatment group scored higher on the posttest.

2) Students engaging in argumentation

The findings in the study showed that students taught using phenomenon-based instructional strategies were engaged in argumentation twice as often as compared to the control group students. The results showed that the treatment group students connected their argumentative reasoning to other applications in the science content more often than the control group. Argumentation has been singled out as an important component in student engagement in science (Ghousseni et al., 2015). By supporting argumentation strategies, like claims, evidence and reasoning, through phenomenon-based instruction allows students to use observations and experimentation data to logically justify why their evidence supports their claims. The combination of high engagement with argumentation skills helps students participate like scientists and develop science literacy (NRC, 2012).

Students in the phenomenon-based instruction treatment group were shown a phenomenon at the beginning of the lesson, then prompted to ask questions to each other while connecting what they already knew about the phenomenon before the concept was presented. Using phenomena permits students not only to build background knowledge with others, but also provides students opportunities to develop claims with evidence and reasoning while they are exploring the science concept through phenomena (Symeonidis & Schwarz, 2016). In contrast, traditional science instruction does not provide the same opportunities for students to access prior knowledge or provide time for student discussion because the lesson's structure is the teacher explaining the concepts and giving the proper science vocabulary before any student exploration takes place (Lee, 2020). For teachers who are looking to have students examine science concepts through multiple applications rather than isolated events and wish to provide students time to talk and argue about their understanding as a community, phenomenon-based instruction is the correct avenue. Phenomenon-based instruction empowers students to articulate their individual reasonings while exploring ideas from the perspective of other classmates while refining and building their conceptual understanding of scientific ideas (Kim, 2001; Taber, 2012).

3) Students exhibiting sensemaking

Sensemaking is based on building background knowledge and engages students in their learning (Odden & Russ, 2019). Using phenomena not only motivates students but helps fit knowledge into students' existing knowledge which can lead to higher-level understanding and applications of the content (Bybee & Van Scotter, 2007). Researchers maintain sensemaking needs to be a part of elementary science classrooms because: (1) sensemaking promotes student engagement and "deep" learning which allows students to actively build connections between new and existing knowledge (Chin & Brown, 2000; Danielak et al., 2014) (2) making sense of ideas facilitates the process of transferring ideas to new and different topics and circumstances (Kapon, 2017; Ruibal-Villasenor et al., 2007).

The findings in this study showed that students who received phenomenon-based instruction engaged in sensemaking at higher levels than those instructed with traditional methods. Students who received phenomenon-based instruction were at times able to transfer the science content learned to other worldly situations. Listening to student discourse statements provided by the iPads, four specific sensemaking applications were verbalized by treatment students as compared to zero sensemaking applications from the control group. When students demonstrate applying science content to relevant situations, both their behavioral and cognitive engagement increases (Guthrie et al., 2004).

Since sensemaking is a form of reasoning that requires students to connect on ideas from investigations, other students' claims, and their own prior knowledge (Kapon, 2017), the results shown in treatment group statements demonstrates the beginnings of students making sense of the science content. The treatment group statements exemplify sensemaking is not completed through memorization of facts, but instead students are connecting to other situations by asking questions like "why" or "how" is this happening. When students are making sense of what they are learning they are engaged and using higher order thinking skills (Colley & Windschitl, 2016). A possible reason for increased sensemaking in the treatment groups is that during the lessons teachers first engage students in wondering and asking questions about a phenomenon before delivering any content. This is followed in the lesson by the teacher presenting an exploratory activity that focuses on science concepts in a different situation. The phenomenon-based instruction lesson structure presses students to practice sensemaking skills to connect the science they are learning in the exploration to the original phenomenon. Sensemaking skills are crucial in helping science literate students apply what they are learning to other situations outside of the classroom (Odden & Russ, 2019).

In conclusion, the qualitative portion of the study affirms that phenomenon-based instruction demonstrates a clear connection between engagement and achievement while implementing discourse, argumentation, and sensemaking. As districts look to focus their professional development on student achievement, leaders need to consider current pedagogical research that can support teachers in engaging their student body. Three key elements that influence effectiveness of student learning and engagement include the classroom culture, instructional practices, and the involvement of students in the lesson (Ryu & Lombardi, 2015; Woodard & Fatzinger, 2018). All three of these elements can all be positively impacted by phenomenon-based instruction.

Recommendations for Further Study

The benefits of this study are two-fold. First, this study shows that phenomena-based instructional practices positively affect student achievement and student engagement in elementary science education. Second, the data gathered can be used in the discussion of elementary science education reform; comparing and contrasting the traditional approach to phenomena-based instruction could support teachers in transforming elementary science education.

One of the goals of this study was to inspire additional research. First, a greater sample size could help collect increased statistically significant results, support triangulation of data, and allow for better saturation of findings/themes (Slavin & Smith, 2008). Further, the combination of quantitative and qualitative data was a key part of this study and it is suggested that future researchers consider a mixed methods approach, especially if/when qualitative data can help support the pinpointing of student engagement in the classroom.

Second, this study was conducted during one week of science instruction, as discussed previously, and could be one of the reasons there was not a statistically significant improvement in conceptual knowledge from the pretest to posttest. A longitudinal study over the course of a semester or an entire year could be extremely beneficial to learn more about if and in what ways phenomenon-based instruction affects conceptual knowledge.

Third, this study was conducted in a single urban school district located in the Northwest and focused on fifth graders. Considering the impact of phenomenon-based instruction on students in light of particular demographics or populations (e.g., gender, ethnicity, English language learners, special needs students, varied grade levels, rural areas, etc.) is suggested. Comparing the effects of traditional science instruction to phenomenon-based instruction among these groups could provide findings that can help schools improve science instruction for all students.

Another area of future study would be exploring if phenomenon-based instruction affects achievement and engagement in other elementary subjects. Different disciplines like math, English Language Arts, and social studies may also benefit from the implementation of phenomenon-based instruction

Lastly, future research should focus on the professional development of teachers in phenomenon-based instruction. In this study, teachers received less than one hour of professional development on phenomenon-based instruction. Research has identified that teachers matter more to student achievement than any other aspect of schooling (Chetty et al., 2014; Rockoff, 2004). Even though many factors contribute to a student's academic performance, including individual characteristics and family and neighborhood experiences, teachers matter the most. Research has also demonstrated that professional development is most effective when it is not content focused, provide active learning opportunities, and have collective participation (Desimone, 2011; Kang et al., 2013) With this stated, additional research needs to continue to determine effective ways to help train teachers in using phenomenon-based instructional components like discourse, argumentation and sensemaking.

Conclusion

At the heart of phenomenon-based instruction is engaging students in communication and exploration to help them understand the world around them more clearly while developing science literacy skills. This study demonstrates that both achievement and engagement gains are made by students when they are actively involved in a relevant phenomenon while using discourse, argumentation, and sensemaking through the process of learning. This study marks a small, but important step in the evolution of current elementary science instruction from traditional methods to phenomenon-based instructional methods with the outcome of students. As one student from Ms. Wray's treatment class exclaimed, "This was the favorite thing I have done all year! I want to see how we can make more chemical reactions like the (inflatable) balloon. Is science always this fun?" This type of excitement in learning science can lead to a lifelong path of wonder and engagement while developing science literate citizens.

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APPENDIX A: LESSON PLAN WITH PHENOMENON-BASED INSTRUCTION

<table>
<tr><td colspan="3" align="center">School District Integrated Curriculum Document (PHENOMENON)</td></tr>
<tr><td><u>Topic:</u> Chemistry</td><td><u>Grade:</u> 5th</td><td>The 5-E document</td></tr>
<tr><td colspan="3"><u>Strand:</u> Physical Science</td></tr>
<tr><td colspan="3" align="center">Learning Outcomes</td></tr>
<tr><td><u>Enduring Understandings/Learning Goal:</u>
Students will explore physical properties of materials and use what they have learned to identify a mystery powder. Students will also investigate how mixing different substances creates a new substance.</td><td colspan="2"><u>Essential Questions:</u>
● What are different ways to classify matter?
● How can I identify materials based on their properties?
● What is the difference between a physical and a chemical change?</td></tr>
<tr><td>Main Resources:
● 5th Grade Science Kit : Chemistry
● Science Textbook: Chapter 11</td><td colspan="2">I Can Statements:
● I can observe and describe properties of matter.
● I can use different properties to help identify objects.
● I can explain the difference between physical and chemical changes.
● I can write a claim, evidence, reasoning explanation on the properties and changes of matter.</td></tr>
<tr><td colspan="3"><u>Science Objectives:</u>
Instructional Objective 3: Make observations and measurements to identify materials based on their properties. (PS1-5-3)

Instructional Objective 4: Conduct an investigation to determine whether mixing of two or more substances results in new substances. (PS1-5-4)

<u>ELA Integration:</u>
RI.5.1 - Quote accurately from a text explaining what the text says explicitly and when drawing inferences from the text.</td></tr>
</table>

RI.5.7 - Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question or to solve a problem efficiently.
RI.5.8 - Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s).
RI.5.9 - Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.
W.5.1 -Write opinion pieces on topics or texts, supporting a point of view with reasons and information.
SL.5.5 - Include multimedia components (e.g. graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

Math Integration:
5.NBT.A.2 - Explain patterns in the number of zeros of the product when multiplying a number by powers of 10, and explain patterns in the placement of the decimal point when a decimal is multiplied or divided by a power of 10.
5.G.A.2 - Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane and interpret coordinate values of points in the context of the situation.

Unit Considerations:

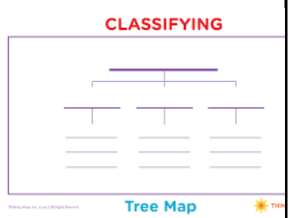
- **Unit Pacing/Cross Curricular Connections:** This unit is designed to be cross curricular. Consider going outside your content blocks for instructional time.
- **Science Notebooks**: Science notebooks are an excellent tool for students to communicate their understanding of science concepts, for teachers to provide students with feedback, and to assess student learning.
- **Thinking Maps:** When using Thinking Maps, encourage students to either **write or draw** their ideas and to use their dominant language, even if not English. It is encouraged to create a Map whole group with student input to model the process and to keep it posted for future reference.
- **Student Discourse:** An important component in science is providing opportunities for students to communicate. This document includes ideas and talk moves to support communication in science.

Lesson 1 Properties of Matter	Lesson 2 Physical Properties of Matter	Lesson 3 Other Properties of Matter	Lesson 4 Physical and Chemical Changes	Lesson 5 Baking Soda vs. Baking Powder

<table>
<tr><th colspan="4">Lesson 1:
Properties of Matter</th></tr>
<tr><td colspan="2">Learning Target: Students will practice describing and classifying matter and learn about specific properties that are used to help classify matter.</td><td colspan="2">Inquiry Essential Question: What are different ways to classify matter?</td></tr>
<tr>
<td><u>Materials:</u>
Teacher Slide Presentation

Mineral phenomenon

<u>Sorting rocks activity:</u>
- bags of rocks
- sorting rocks handout

Matter article</td>
<td><u>Graphic Organizer/Science Notebook:</u>
Create a tree map to help classify different properties of matter.


In a science notebook or on an index card for an exit ticket, fill out the sentence starter frame.</td>
<td><u>Teacher Tips:</u>
Tell students that you will be using the word sort and classify synonymously - Classify is the science term.
Mass and weight are difficult terms for 5th graders. Mass is the amount of matter in an object while weight is how strong gravity pulls on an object. On Earth our mass and weight are the same measurement, where it gets tricky is on different planets or in space.</td>
<td><u>Vocabulary:</u>
Matter
Classify
Mass
Weight
Properties</td>
</tr>
<tr><td colspan="4">Engage:
1. Show the phenomenon of the newly discovered mineral (over exaggerate that this mineral was found in Africa recently and sent to our school to help identify it - it is really amethyst crystals embedded in an igneous rock). Ask the following questions to the class (don't not give any answers - the phenomenon is used to not only engage, but to listen to what the class already knows)
a. What do you notice?
b. How can we identify an unknown substance?
c. How would you describe this mineral?
d. What other questions do you have?</td></tr>
</table>

Explore:

1. Big Question: What are different ways we can classify objects?
2. Materials:
   a. Bags of different rocks/minerals
   b. Sorting rocks handout
3. Procedure:
   a. After showing a bag of rocks have students predict, what are some ways you can sort/classify different rocks? Record on handout.
   b. Group students and pass out a bag of rocks to have students sort and classify how they want. Record the way they sorted the rocks on their handout.
   c. Come back together as a whole group and have each group explain how they sorted their rocks. Create a class list of all the different ways groups sorted the rocks. Some examples could be size, shape, color, hardness, etc.
   d. Groups will go back to their rocks and sort a different way from the first time you classified the rocks. Students can use ideas from the class list or create a new way they have come up with. They will leave these rocks sorted on their table for other groups to guess how they have sorted the rocks.
   e. Have students go to five other groups and try to determine how each group sorted their rocks. Record this information on the sorting rocks handout.
   f. Come back as a whole class, ask does anyone know the science word that describes all the different categories/classifications that were used to sort the rocks? (answer -properties - students might say characteristics)

Explain:

1. *Key vocabulary:*
   a. Everything around us is matter
      i. Matter takes up space and has weight (mass) - In fifth grade you do not need to differentiate between mass and weight so you can decide what term to use
   b. All matter can be classified by its properties (characteristics)
      i. Examples of properties of matter:
         1. Color
         2. Shape
         3. Texture - What an object feels like
         4. Hardness - how hard or soft
         5. State - solid, liquid or gas
2. Create a class tree map of different types of properties of matter. (example on

slide show)
3. During the ELA block, have students read the article on matter - Use critical reading strategies such as number paragraphs, highlighting the main idea, drawing a picture of what the paragraph is about in the margin, partner read, etc.

Elaborate:
1. Complete this activity with a partner, the first partner will choose a picture and describe the properties of each to a partner. (example questions)
    a. What does it look like?
    b. How do you think it would feel in your hands?
    c. How would you describe it?
2. The second partner will try to guess which picture their partner is describing.
3. Repeat the process but the second partner will choose a picture and describe the properties.

Evaluate:
1. Revisit the phenomenon by showing the class the newly discovered mineral again. Ask the following questions, but try to let students drive this discussion.
    a. What properties can we use to identify this mineral?
    b. How would you describe this to someone who couldn't see it?
    c. What questions do you still have? (you do not need to answer these questions, they are wonder questions)
2. In a science notebook complete the 3-2-1 exit ticket:
    a. What are three properties of matter?
    b. What are two ways to describe matter?
    c. What is one question you still have about matter?

Lesson 2: Physical Properties of Matter			
Learning Target: Students will observe and use physical properties to identify four white powders and write a CER explanation on a mystery powder.		**Inquiry Essential Question:** How can I use physical properties to help identify materials?	
Resources: Teacher Slide Presentation Phenomenon video	**Graphic Organizer/Science Notebook:** This is the first CER students will be writing. Go	**Teacher Tips:** The white powder activity has many components, so it is best to go step by step together as a	**Key Vocabulary:** Physical properties Solubility Texture Claim Evidence

White powder activity: - four white powders (salt, flour, cornstarch, baking soda) - hand lens - plastic cups - paper plates - spoon - stirring stick - task card - student data sheet Crash Course video Properties article CER template	over the way to write a CER using the template. Practice by watching the alien video and as a class write a claim with evidence and reasoning. The CER mystery white powder is Epsom Salt - even though students have not identified this particular kind of salt they should be able to follow the same tests as the explore activity to determine this is a type of salt.	whole class demonstrating how to do all the tests of one white powder and then let the groups do the other three white powders independently.	Reasoning

Engage:

1. Show the phenomenon of the egg breaking in slow motion - video Ask the following questions to the class (don't not give any answers - the phenomenon is used to not only engage, but to listen to what the class already knows)
    a. What did you notice in the video?
    b. What did you observe about the egg before it was cracked?
    c. What did you observe after the egg has cracked? - Watch the video again
    d. What other questions do you have?

Explore:

1. Big Question: How can you identify white powders using physical properties?
2. Materials:
    a. Four powders (salt, flour, cornstarch, baking soda)
    b. Materials used for testing (hand lens, plastic cups, paper plate, spoon, stirring stick, task card)
    c. Student data sheet
3. Procedure:
    a. Create student groups and hand out all the materials to groups of

students. Project and read the task card to the whole class.

b. As a whole class, have students follow along and conduct all the tests on the task card for salt. Together as a group record on the student data sheet.
c. Groups will individually complete the tests for the other three white powders and record on the data sheet.
d. Either go over the data of the three white powders as a whole class or create a jigsaw discussion where one member of each group goes to a different group to create a new group and compare the results of the data table of the three other white powders.

Elaborate:

1. Bring the whole class back together to discuss argumentation in science. Ask the following questions to the class:
   a. Did anyone have different observations or results from your white powders exploration?
   b. Do you think disagreeing in science is a good or bad idea? Why?
   c. Why do you think scientists might have different explanations about the same data? (Use some of the situations from the data collected in the white powder exploration)
2. Extension (If you have time): Read the first half of the pdf document of "Why do Scientists Disagree?"

Explain:

1. *Key vocabulary:*
   a. Physical properties can be measured and observed without changing the matter into something else
   b. Solubility - does it dissolve in water (physical property)
2. Watch Crash Course video on the properties of matter
3. During the ELA block, have students read article on matter - Use critical reading strategies such as number paragraphs, highlighting main ideas, drawing a picture of what the paragraph is about in the margin, partner read, etc.

Evaluate:

1. Revisit the phenomenon by having the students watch the egg cracking video again. Ask the following questions, but try to let students drive this discussion.
   a. What different physical properties of the egg did you observe this time?
   b. What other questions do you still have? (you do not need to answer these questions, they are wonder questions)
2. Claim, Evidence, Reasoning (This could be new for students so take your time explaining this first time through)
   a. Watch the video explaining CER and discuss the 3 components of a CER

i. Claim (the answer) - one sentence answer to what you believe to be true and answers the question.
ii. Evidence (the clues) - One or two sentences of your data that supports your claim
iii. Reasoning (the why) - Use science vocabulary to create an explanation of why you believe your claim.

b. Practice a CER by watching this video (2 times). Find the girl's claim, at least one piece of evidence and why she reasons/believes her claim to be correct. (example - my dad is an alien, he has a spaceship, aliens have spaceships so my dad is an alien)

3. Project the template of how to write a CER for students (or have a print copy for each student to put in their science notebook). Have students look at the picture and hand out a small cup of this substance (Epsom Salt) for students to observe and test before writing their CER.
    a. Claim: Which white powder do you think this is? (salt, flour, cornstarch, baking soda)?
    b. Evidence: Cite at least one piece of evidence from what you have learned to support your claim.
    c. Reasoning: Use scientific vocabulary that shows an understanding of the concept.

<table>
<tr><th colspan="4">Lesson 3:
Other Properties of Matter</th></tr>
<tr><td colspan="2">Learning Target: Students will test three other physical properties, conductivity, reflectability, and magnetism and then write a CER explanation analyzing property data on a graph.</td><td colspan="2">Inquiry Essential Question: What other physical properties can help identify materials?</td></tr>
<tr><td>Resources:
Teacher Slide Presentation

Magnetic goo and magnet

Test properties</td><td>Graphic Organizer/Science Notebook:
Create a class circle map of the word property - looking at words to describe or give examples of</td><td>Teacher Tips:
This exploration investigation is pushing the students to try to determine how to use the testing equipment to find out if the objects</td><td>Key Vocabulary:
Properties
Magnetic
Conductive
Reflective
Flexible</td></tr>
</table>

activity: - Bag of materials to test (metal spoon, plastic spoon, nail, craft stick, aluminum foil) - Bag of testing materials (magnet, laser, battery, battery holder, lightbulb) - Student data sheet Properties article 21 question cards Phenomenon video	different properties they learned about.  This is the second CER so students should be a little familiar with the format - use this template to help with scaffolding.	have the properties of magnetism, conductivity, and reflectivity.	

Engage:

1. Gather students around and show them the mystery substance (Magnetic Goo). After showing them some of the actions the goo can perform with a magnet ask the following questions. (don't not give any answers - the phenomenon is used to not only engage, but to listen to what the class already knows)
    a. What do you notice about the mystery substance?
    b. What are some of the properties of this substance?
    c. Which state of matter do you think this substance is (solid, liquid or gas)?
    d. What other questions do you have?

Explore:

1. Big Question: Which materials conduct electricity, attract magnets, and reflect light?
2. Materials:
    a. Bag of testing materials (metal spoon, nail, craft stick, plastic spoon, aluminum foil)
    b. Materials used for testing (magnet, laser, battery, battery holder, lightbulb)

    c. Student data sheet
3. Procedure:
    a. Explain that each group will be testing five objects (metal and plastic spoon, nail, craft stick, and aluminum foil) to see if the object has the physical properties of conducting electricity, reflecting light, or being attracted to a magnet.
    b. Make a prediction on the data sheet which objects your group thinks have these properties.
    c. Show the five materials (magnet, laser, battery, battery holder, lightbulb) that will be used to test each property. Have the groups brainstorm their ideas of how they will use each tool to test for the property. If students struggle coming up with what to do, ask questions to get them to come up with the solution.
    d. One student from each group will gather all the materials. Take 12 minutes to test each physical property using the materials you gathered and record information on the data sheet.
    e. Discuss the reflection questions on the data sheet with your group.

Explain:

1. *Key vocabulary:*
    a. Other physical properties of matter include:
        i. Reflectivity - does it reflect light
        ii. Magnetic - does it interact with a magnet
        iii. Conductivity - does it conduct electricity
2. During the ELA block, have students read the article on different properties of matter. One possible strategy to use is a jigsaw (link with idea). Since there are 5 properties on this reading, have each small group just read one of the properties and then on a piece of construction paper create a visual representation that they will use to teach this property to the rest of the class.

Elaborate:

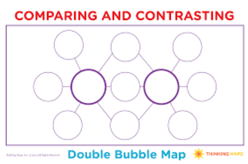
1. Create a class circle map on the word property - looking at words to describe property or types of properties the class has learned.
2. Extension (If you have time): Play 21 question properties game using these cards.
    a. Pick a matter card from the pile and do not share what it is with your group.
    b. Other students in your group take turns asking 21 yes or no questions to figure out what is on the card. (Each guess of the card takes one of the 21 questions).
    c. The questions that are being asked should be about physical properties like color, hardness, solubility, reflectability, flexibility, etc.

d. After the image is guessed, another student picks a different card and the questions start over.

Evaluate:

1. Revisit the phenomenon by watching this video of the mystery magnetic goo. Ask the following questions, but let students drive the discussion:
    a. What physical properties could you use to help identify this substance? Explain your thinking.
    b. What questions do you still have about the mystery goo?
2. Claim, evidence, reasoning activity:
    a. Read the scenario to the class - **Scenario:** Unknown substances were placed into balloons. Students were asked to try to identify them by testing their properties. The data collected is shown in the table below.
    b. Write a scientific explanation following the Claim - Evidence - Reasoning pattern and using the template to answer the question - which balloon contains iron?
        i. Claim: Which balloon contains iron?
        ii. Evidence: Cite at least two pieces of evidence from what you have learned or is in the table to support your claim.
        iii. Reasoning: Use scientific vocabulary that shows an understanding of the concept.

Lesson 4: Physical and Chemical Changes	
Learning Target: Students will investigate four stations that show changes in materials and will determine which are physical changes and which are chemical changes.	**Inquiry Essential Question:** What is the difference between a physical and chemical change?

Resources:	**Graphic Organizer/Science Notebook:**	**Teacher Tips:**	**Key Vocabulary:**
Teacher Slide Presentation Phenomenon videos: - ice video - banana video Jar and matches Changes Stations: **Station 1:** - bubble wrap **Station 2:** - cup of baking soda - cup of vinegar - wax paper - spoon **Station 3:** - clay **Station 4:** - cup of milk - cup of vinegar - empty cup - stirring stick - graduated cylinder Matter changes video	Create a class double bubble thinking map on the similarities and differences of physical and chemical changes. 	Set up 8 stations (2 of each of the 4 stations) to allow for eight groups. Having roles for students helps with stations - for example one student is the time keeper, one student reads the directions, one student makes sure all students are recording the data on their paper.	Physical change Chemical change

Engage:

1. Show the two phenomenon videos (ice video and banana video) having students paying close attention to the changes that occur in each video. Ask the following questions to the class (don't not give any answers - the phenomenon is used to not only engage, but to listen to what the class already knows)
   a. What changes did you notice in the videos?

b. Describe what some differences between the two videos were and how things changed?
c. Can either of these changes be reversed?
d. What other questions do you have about these changes?

Explore:

1. Hold up a piece of paper to show the whole class. Ask what are some different ideas how we can change this piece of paper? (ex - rolling it, cutting it, tearing it, writing on it, etc.)
   a. Show a couple of these ideas like rolling and cutting and ask the students with the changes we made is this still paper?
2. Tell the students I am going to change it another way by following these steps:
   a. Roll up the piece of paper and put it in the jar.
   b. Ask the students to predict what will happen to the paper when I drop a lit match in the jar with it?
   c. Strike a match and drop it in the jar for students to observe
   d. Ask the students if this change is still paper? How do you know?
3. Matter Stations:
   a. Big Question: What kind of changes can I observe?
   b. Materials: four station materials (in unit plan), student data sheet
   c. Procedures:
      i. Set up the 4 stations (Station 1: Bubble Wrap, Station 2: Baking Soda and Vinegar, Station 3: Clay, Station 4: Milk and Vinegar) where the students will explore the station for 4 -5 minutes at each station (use a timer). One management tool is to have two set ups of each of the 4 stations so that a total of 8 groups can be created.
      ii. At each station, one student will read the directions on the data sheet. The group will then complete the activity and record all the information on their data sheet.
      iii. Another student will be the time keeper so that at the end of 4 minutes the group will have one minute to clean up the station before the group moves to the next station.
   d. Students will share their information on the stations after the explain section!

Explain:

1. *Key Information:*
   a. There are two main changes of matter:
      i. Physical Change: A type of change which a new substance is NOT formed (ex. water boiling or freezing)
      ii. Chemical Change: A type of change which a new substance is

formed (ex. burning something)

b. Watch video on changes of matter
c. During the ELA block, have students read the infographic article on changes in matter - Use critical reading strategies such as number paragraphs, highlighting main ideas, drawing a picture of what the paragraph is about in the margin, partner read, etc.

Elaborate:

1. Create a class double bubble map on physical and chemical changes.
2. Go over the 4 stations data sheet as a whole class to identify the types of changes at each station.

Evaluate:

1. Revisit the phenomenon by watching the two videos again and asking the class the following questions, but let students drive the discussion:
    a. What type of changes do you think these changes are?
    b. What evidence do you have to make this claim?
    c. What other questions do you still have?
2. Claim, evidence, reasoning activity:
    a. Write a scientific explanation following the Claim - Evidence - Reasoning pattern and using the template to answer the question - Is rust a physical or chemical change?
        i. Claim: Is rust a physical or chemical change?
        ii. Evidence: Cite at least two pieces of evidence from what you have learned to support your claim.
        iii. Reasoning: Use scientific vocabulary that shows an understanding of the concept.

<table>
<tr><th colspan="4">Lesson 5:
Baking Soda vs. Baking Powder</th></tr>
<tr><td colspan="2">Learning Target: Students will investigate the different properties and chemical reactions of baking soda and baking powder to reinforce their knowledge before the post assessment.</td><td colspan="2">Inquiry Essential Question: How are baking soda and baking powder different?</td></tr>
<tr><td>Resources:
Teacher Slide Presentation</td><td>Graphic Organizer/Science Notebook:</td><td>Teacher Tips:</td><td>Key Vocabulary:
Baking soda
Baking powder</td></tr>
</table>

Self-inflated balloon Explore activity: - baking soda - baking powder - small cups - clear 9oz cups for demo -vinegar Extension activity: - 2 balloons - two small water bottles - vinegar - baking soda - baking powder Changes article			

Engage:

1. Demonstrate to the class the self-inflating balloon by putting the package on a table and then pounding it with your fist. Ask the following questions to the class (don't not give any answers - the phenomenon is used to not only engage, but to listen to what the class already knows)
    a. What did you notice?
    b. What change (physical or chemical) do you think is happening? What evidence do you have?
    c. Why do you think this change is happening?
    d. What other questions do you have?

Explore:

1. Big Question: How can we create an experiment to compare the reactions when vinegar is mixed with baking soda compared to baking powder?
2. Materials:
    a. Small cups of baking soda and baking powder for pair of students to observe
    b. cup of baking soda
    c. cup of baking powder

   d. vinegar
3. Procedures:
   a. Hand out the both powders to pairs of students to observe. Point out that even though the two white powders look similar, there may be differences between them. Ask students if they can suggest a test or property that might be used to show that they have different characteristics. (like solubility, texture, appearance, etc.)
   b. Ask the class the big question and come up with shared ideas (write on the board) - Lead a discussion to help students design a test to compare the reactions of baking soda and baking powder with vinegar. Ask leading questions to encourage students to realize that to determine whether the reactions of the two powders are different the baking soda and baking powder must be tested in the same way. Sample questions could include:
      i. Should we use the same amount of baking soda and baking powder in the test? (yes)
      ii. Should we add the same amount of vinegar to the baking soda and to the baking powder? (yes)
      iii. Is it important to add the vinegar at the same time to the two separate cups containing baking soda and baking powder? Why or why not? (answer - testing the two reactions side-by-side, by adding vinegar to the two cups at the same time, makes it easier to compare not only how much bubbling is produced, but also how fast the bubbles are produced. Alternatively, you could also mark the level of bubbles produced in each cup and time how fast it takes the bubbles to rise in each cup.)
4. This activity works best as a demonstration instead of having each group setting up their own experiment. Below is a sample of how to set up the experiment for the students:
   a. Place ½ teaspoon of baking soda and ½ teaspoon of baking powder into their labeled cups.
   b. Add 2 teaspoons (10 milliliters) of vinegar to each of the two empty cups labeled Vinegar.
   c. Using a dropper, add 1 drop of detergent solution to the vinegar in each cup. Gently swirl to mix.
   d. Pour vinegar from both cups into the baking soda and the baking powder at the same time. Compare how the two solids react with vinegar. (Expected results - The baking soda reacts faster and produces more bubbles than the baking powder.)
5. Ask students what they observed and what kind of change do you think

occurred (answer - The baking soda reacted faster with vinegar than baking powder did and also produced more bubbles. The baking powder also bubbled when vinegar is added, but the overall reaction was slower and the bubbles did not rise as high in the cup as they did with baking soda.)

6. Show animation of the experiment to explain the science

Extension (if you have time):This activity shows the different amount of gas baking soda and baking powder create:

1. Put the same amount of vinegar (2 TBsp) into two small clear water bottles.
2. Put the 1 tsp. of baking soda in one balloon and 1 tsp of baking powder in the other balloon.
3. Attach the balloons to the top of the bottles, but don't let the powder drop into the vinegar!
4. Predict which balloon do you think will blow up fuller - explain why.
5. At the same time lift the balloons up so that the powders drop in the bottles and observe what happens.

Explain:

1. *Key Information:*
    a. Chemical changes usually occur when there is either a color change, formation of a gas (fizzing), or change in temperature
2. During the ELA block, have students read the article on changes in matter - Use critical reading strategies such as number paragraphs, highlighting main ideas, drawing a picture of what the paragraph is about in the margin, partner read, etc.

Elaborate:

1. Identify whether the picture is either a physical or chemical change. Using the think. Pair, share strategy have students give evidence on why you made this claim. (answers - A and C are physical changes, B and D are chemical changes)

Evaluate:

1. Revisit the phenomenon by demonstrating another self inflating balloon. Ask the following questions:
    a. What kind of change do you think is happening?
    b. Why do you think this kind of change is happening?
    c. Do you think you could make an inflatable balloon that can be reusable?
    d. What questions do you still have?
2. Take Post Assessment exam

APPENDIX B: POST/PRE ASSESSMENT

Pre/Post Assessment

Identification # _________________ School ________________ Date ___________

_____ Control Group _____ Treatment Group

Part A: Multiple Choice:

1) Read through this table comparing four different metals to answer the question below:

Metal	**Color**	**Magnetic**	**Electrical Conductivity**
Iron	Gray	Yes	Good
Copper	Red/ Brown	No	Good
Aluminum	Gray	No	Fair
Nickel	Gray	Yes	Fair

A sample of an unknown metal is gray, magnetic, and a good conductor of electricity could most correctly be identified as _____.

a) Iron
b) Copper
c) Aluminum
d) Nickel

2) How are you able to determine the physical properties of a substance?

a) By using your senses to smell, taste, hear, feel, or see it.
b) By comparing it to the substances that surround it
c) By determining its placement on the periodic table of elements
d) By observing how it reacts to other substances

3) The ability of matter to dissolve in a liquid is called ________.

a) Solubility
b) Reflectivity
c) Conductivity
d) Magnetism

4) What property do a steel screw, an iron nail, and a paperclip have in common?
   a) They all have the same weight
   b) They all have the same shape
   c) They are all soluble in water
   d) They are all magnetic

5) Information on three similar powders is listed below:

Type of Powder	**Color**	**Soluble in Water**	**Reacts with Vinegar**	**Solution Conducts Electricity**
Baking Soda	White	Yes	Yes	Yes
Cornstarch	White	No	No	No
Talcum	White	Yes	No	Yes

A student believes the identity of an unknown substance is baking soda. Which of the following tests will be most helpful in confirming the identity of the powder?
   a) Adding a small amount of vinegar to the powder
   b) Dissolving the powder in a beaker of water
   c) Testing the electrical conductivity of it in a solution
   d) Comparing the color of the powder to other powders

6) The table below shows four different experiments. Which one is a chemical change?

Experiment	**Procedure**
A	Mix several different candies in a bowl
B	Take a cup of water and put it in the freezer
C	Burn a piece of paper
D	Cut a sheet of paper into small pieces

a) A
b) B
c) C
d) D

7) When water changes from a liquid to a solid this is an example of
   a) a physical change.
   b) solubility.
   c) a chemical change.
   d) reflectability.

8) Which of the following is a chemical change of the picture below?

   a) The object is picked up by a magnet.
   b) The object will rust when left outside in the rain.
   c) The object is bent into a circle.
   d) The object is placed in water and is not soluble in water.

Part B: Free Response:

1) Katie and Bryan found a piece of metal on the playground at school. The Sun was shining brightly and the light reflected off the silver metal. Bryan picked it up. It felt warm from the heat. They carried it into the classroom and found it was not attracted to a magnet. They discussed the possible metals it could be. They narrowed it down to three kinds: **iron, copper, or aluminum**. Use your knowledge of physical properties to help them figure out what kind of metal they found.

Metal	**Iron**	**Copper**	**Aluminum**
Color	Gray	Yellow orange	Shiny silver
Conductivity	Yes	Yes	Yes
Magnetism	Magnetic	Nonmagnetic	Nonmagnetic

Reflectivity	Reflective	Reflective	Reflective
Solubility	No	No	No

What type of metal did they find? ____
Give at least two reasons why you think it is this type of metal.

a)

b)

2) Write a claim evidence reasoning statement to the following scenario:

You and a friend pour vinegar into a Ziploc bag of baking soda. After you seal the bag you observe fizzing and bubbling occurring in the bag. The bag begins to expand and the materials inside the bag begin to feel cold.

- Claim: Is this a physical or chemical change?
- Evidence: Cite at least two pieces of evidence from what you have learned to support your claim.
- Reasoning: Use scientific vocabulary that shows why you think this is either a physical or chemical change.

Claim:

Evidence: 1) 2)

Reasoning:

APPENDIX C: FREE RESPONSE ASSERTIONS FOR CONCEPTUAL QUESTIONS

Question 9: (Possible 3 points)

The student selected aluminum. This provides evidence of the ability to make observations to identify materials based on properties.	**1 pt.**
When asked to provide evidence for their reasoning on choosing the metal, the student provided some evidence about the metal being non metallic unlike the other metals provided.	**1 pt.**
When asked to provide a second piece of evidence for their reasoning on choosing the metal, the student provided some additional evidence about the metal being silver unlike the other metals provided.	**1 pt.**

Question 10: (Possible 4 points)

The student will make a claim that the scenario is a chemical change. This provides evidence that the student can determine when two or more substances are mixed may result in a new substance.	**1 pt.**
When asked to provide evidence to defend their claim, the student will provide evidence about the bubbling and/or fizzing they observe when they mix the two substances supporting the claim is a chemical change.	**1 pt.**
When asked to provide evidence to defend their claim, the student will provide evidence about the bag expanding and/or a temperature change they observe when they mix the two substances supporting the claim is a chemical change.	**1 pt.**
The student will use scientific vocabulary, like properties, changes, fizz and bubbles support chemical change, etc. to show reasoning with their claim. This provides evidence that the student can explain why their evidence supports their claim.	**1 pt.**

APPENDIX D: POST QUESTIONNAIRE FOR PARTICIPATING TEACHERS

Post Questionnaire for Participating Teachers

Please answer the following questions about your experience in the science study.

1) **What were the benefits of the science lessons you taught?**
2) **What were the drawbacks of the science lessons you taught?**
3) **What component(s) of the science lessons helped you teach your students the content most effectively?**
4) **What component(s) of the science lessons helped engage your students most effectively?**
5) **What component(s) of the science lessons supported your students in making claims with evidence?**
6) **What did your students say about the science lessons? (Any quotes would be great)**

APPENDIX E: ENGAGEMENT INSTRUMENT

Engagement Instrument

Teacher ______________ **Date _____________**

_____ Control Group _____ Treatment Group

Part A: Number of Science Questions Asked by Students during the Lesson:

Part B: Number of Specific Science Vocabulary Used during the Lesson:

Properties	Texture	States of Matter
Magnetic	Conductivity (Electrical)	Reflectivity
Physical Change	Chemical Change	Dissolving

Part C: Number of Statements Demonstrating Students Using Evidence to Defend Claims:

APPENDIX F: IRB

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT
Research Compliance

Date: June 15, 2021

To: Sara Hagenah cc: Chris Taylor

From: Social & Behavioral Insitutional Review Board (SB-IRB)
c/o Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval - Original - 101-SB21-105
Phenomenon-based instruction in elementary science classrooms

The Boise State University IRB has approved your protocol submission. Your protocol is in compliance with this institution's Federal Wide Assurance (#0000097) and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Protocol Number: 101-SB21-105	Received: 6/1/2021	Review: Expedited
Expires: 6/14/2022	Approved: 6/15/2021	Category: 7

Your approved protocol is effective until 6/14/2022. To remain open, your protocol must be renewed on an annual basis and cannot be renewed beyond 6/14/2024. For the activities to continue beyond 6/14/2024, a new protocol application must be submitted.

ORC will notify you of the protocol's upcoming expiration roughly 30 days prior to 6/14/2022. You, as the PI, have the primary responsibility to ensure any forms are submitted in a timely manner for the approved activities to continue. If the protocol is not renewed before 6/14/2022, the protocol will be closed. If you wish to continue the activities after the protocol is closed, you must submit a new protocol application for SB-IRB review and approval.

You must notify the SB-IRB of any changes to your approved protocol and the committee must review and approve these changes prior to their commencement. You should also notify the committee if your activities are complete or discontinued.

Current forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.