CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

SHIFTING FROM TEACHER-CENTERED TO STUDENT-CENTERED SCIENCE TEACHING AND ITS IMPACT ON STUDENT ACHIEVEMENT, MOTIVATION, AND ENGAGEMENT IN FOURTH-GRADE

A thesis submitted in partial fulfillment of the requirements

For the degree of Master of Arts in Education, Elementary Education

By

Melissa Wendorf

December 2018

The thesis of Melissa Wendorf is approved:

Dr. David Kretschmer	Date
Dr. Raymond Brie	Date
John M. Reveles, Ph.D., Chair	Date

California State University, Northridge

Table of Contents

List of Figures

List of Tables

Abstract

Shifting from Teacher-Centered to Student-Centered Science Teaching and its Impact on Student Achievement, Motivation, and Engagement in Fourth-Grade

By

Melissa A. Wendorf

Master of Education, Elementary Education

With an emphasis on the Next Generation Science Standards (NGSS), this thesis examined traditional teacher-centered versus student-centered science instruction in a fourth-grade elementary school classroom. As part of a two year study, the following variables were measured: (a) student academic achievement, (b) student motivation, and (c) student engagement. A total of sixty-eight fourth-grade students participated in this study. Throughout the 2017-2018 academic year, thirty-two students took part in the initial student-centered science class. During the 2018-2019 academic year, thirty-six students participated in a completely student-centered science classroom. Across both academic years, and during a twelve-week unit on Energy and Waves, students interacted in groups with weekly investigations, answered relevant questions, and participated in whole-class discussions. A comparison between eighteen students in the initial (2017-

2018) student-centered (shifting from teacher-centered) classroom and eighteen students in the completely (2018-2019) student-centered classroom was conducted. Student data was collected in the form of (a) student science notebooks, (b) student science achievement scores, (c) interest in science surveys, and d) student motivation and engagement rubrics. Study results indicate that student academic achievement in science increased when the completely student-centered instruction was utilized. In addition, student motivation and engagement towards the content being taught increased when the completely student-centered approach to teaching science was used by the teacher. This study provides important findings regarding the transition from traditional teacher-centered science instruction to the use of an NGSS oriented student-centered teaching approach.

CHAPTER I: INTRODUCTION

The Need to Transform Science Teaching in the 21st Century

Jobs in the 21st century are changing and require the preparation of a workforce that is equipped with the skill sets to meet the demands of a rapidly changing society. The importance of science, technology, engineering, and math (STEM) in U.S. job fields cannot be understated, it is crucial for K-12 students to develop a passion and excitement for STEM learning during their primary education years for them to excel in the future. According to Marrero, Gunning, and Germain-Williams (2014), STEM defines both education and careers in sciences, math, social science and other related fields. For this reason, it is essential to teach STEM skills through student-centered instruction to be successful in a 21st century workforce. As educators, it is important that all students, "regardless of race, ethnicity, ability, language, gender, or location" are taught the skills needed for STEM careers (Marrero, Gunning, & Germain-Williams, 2014, p. 1). With more jobs in the United States geared towards the sciences, there is a need for emphasizing STEM related majors. Unfortunately, colleges in the United States have high attrition rates in STEM programs. From the few students that do enter into a STEM related major, even fewer stay in the major and go on to earn a STEM related degree (Chen & Soldner, 2013). High attrition rates in STEM related majors may be due to a deficit in STEM skills developed during K-12 science education experiences. Unfortunately, many of these college bound students were taught science utilizing traditional teaching styles. In traditional science classrooms, teachers often use lecture-based teaching which fails to provide instructors with feedback regarding student learning under the assumption that all students learn at the same pace and style.

Additionally, traditional science learning emphasizes learning by listening which can be a disadvantage for those students who have other learning styles (Schwerdt & Wuppermann, 2011). If college students are not trained to be critical thinkers and good problem solvers during their K-12 science experiences, it is presumed that they will continue to leave STEM majors at significantly diminished rates. Thus, precipitating the need to keep importing increasing percentages of scientists, engineers, and mathematicians into the U.S. rather than training them from the existent citizenry.

With the increasing use of technology in daily life, society has created a debate regarding its role in the lives of young children. According to the National Center for Education Statistics (2013), seventy-one percent of the U.S. population age three and above, use the Internet. On a weekly basis, children spend much of their free time watching television, playing video games, using smartphones, tablets, and iPads, which are all surrounded by quick moving media forms. Because of frequent use of this type of technology at home, teachers are faced with the challenge of continuously finding new ways to keep students engaged, since sitting at a desk and learning science in traditional ways can be daunting for students. With technology becoming such a prevalent part of society, STEM teaching is becoming increasingly popular in today's K-12 classrooms. Therefore, in order to adequately prepare a 21st century STEM workforce, teaching science at all grade levels needs to shift from a teacher-centered approach to a student-centered classroom.

Traditional Teaching Versus Student-Centered Instruction

Teachers are always looking for the most beneficial approach to instruction as they want students to enjoy the learning process while maintaining order and control in the classroom. High levels of boredom during instruction has inspired research on student engagement and its effects on student achievement in the classroom (Fredricks, Blumenfeld, & Paris, 2004). In recent years, there has been much debate regarding the different approaches to how instruction should be taught—traditional or teacher-centered instruction versus student-centered instruction (McComas, 2002). It is unclear whether students are learning at a higher, conceptual level of thinking with teacher-centered approaches. Pederson and Liu (2003), provide insightful information about the differences between the two types of learning: In a teacher-centered approach, students work to meet objectives set by a teacher. In contrast, student-centered instruction has students "work to provide a response to a central question" (Pederson & Liu, 2003, p. 58). A teacher-centered classroom is how a traditional classroom is organized. The teacher follows the textbook lesson-by-lesson and at the end of each chapter, students take a test, and the process starts all over again. The teacher follows the set objectives by the textbook and can repeat the same planning year-after-year. On the other hand, in a student-centered classroom, the teacher allows students to explore a question, and determine the answer through their own problem solving. Unlike a teacher-centered approach where students may complete an investigation to explain a concept, in a student-centered classroom, students begin with an investigation to build and form their ideas about scientific concepts.   From a student-centered perspective, students use their own experiences to gain a deeper understanding of scientific phenomena. On the other hand, in a traditional classroom students are passive in their learning and are receivers of ideas, concepts, and knowledge from the teacher who decides the exact nature of the learning tasks. In contrast, in a student-centered classroom, students are actively seeking answers and engaging with the content more like scientists, engineers, and mathematicians.

Student-Centered Science Learning Using Technology

Advances in computer related technologies have facilitated the process of making student-centered alternatives both possible and feasible (as cited in Hannafin & Land, 1997). This has become a teaching reality because implementing technology in the classroom is not the only way to cultivate student led learning in the classroom. However, it does offer a relevant tool for teachers to use that keeps students engaged in the learning task. In a science classroom, teachers must provide meaningful instruction where students are investigating and exploring scientific phenomena through hands-on learning. With technology as a tool, teachers can allow students to be more autonomous in their science learning by using computers, tablets, and smart phones to mediate instruction. In utilizing technology (which often times students are extremely proficient at using) as a mediator of understanding, students can naturally gain a deep conceptual understanding of a science topic based on their own classroom experiences. As technology becomes more integrated into the classroom, there will be additional opportunities for student-centered approaches to learning.

Shifting to the Next Generation Science Standards (NGSS)

The original California science standards created in 1998 asked students "to know" important facts and information (Ong & Bruton, 2000). Being asked to describe is a lower level of knowledge according to Bloom's Taxonomy of higher order thinking (as cited in Churches, 2008). Updated standards—the Next Generation Science Standards (NGSS)—emphasize more critical thinking and investigation, and have been created to reflect a more student-centered shift for engaging students in science learning in more applicable and meaningful ways. According to Benjamin Bloom's Taxonomy of Higher Order Thinking, being able to analyze, evaluate, and create are the highest levels of thinking in ones' synthesis of a topic (as cited in Churches, 2008). Thus, in 2013, the new science standards created a huge shift in the way students are expected to understand content. The NGSS want students to "use evidence," "make observations," "ask questions and predict outcomes," "develop models," "generate and compare solutions," "construct arguments," "identify patterns," "analyze and interpret data;" all terms used in the highest form of Bloom's Taxonomy (NGSS, 2013). With recent shifts in the science standards, students must demonstrate their mastery of a topic in a deep and meaningful way.

The NGSS have generated a shift in the way K-12 teachers are being asked to teach science. The goal of the NGSS is for students to understand core scientific concepts while emphasizing critical thinking and investigating skills. The Next Generation Science Standards deepen the concept of inquiry-based science and are developing classroom practices that are a representation of what true scientists do as they engage in scientific practices (Quinn, Lee & Valdes, 2012). This is a powerful way to shift the emphasis from just learning science as a passive recipient of information and knowledge, to learning science by learning to do science in ways that actual scientists in the real world engage in the scientific enterprise. The implementation of the NGSS require a shift from the traditional teacher-centered instruction to student-centered instruction in order for students to learn to engage in science in similar ways that practicing scientists do.

Unfortunately, with a lack of updated textbooks and sufficient professional development on the new science standards, many teachers are resistant to implement a student-centered approach in their own science classrooms. In many Los Angeles Unified School District schools, few teachers have even begun to implement the NGSS in their classrooms. The reason they point to is that the curriculum and textbooks that they have, do not pertain to the NGSS. Teachers also find it challenging to get needed funding to afford the required materials to properly implement NGSS instruction. Without new curricula, many teachers are not willing to put in the time and effort needed to teach using the new standards and apply a different approach to teaching science from a more student-centered perspective. Not only can the price of the curriculum be very expensive, having the funds to get sufficient materials needed for exploration can add up quickly. What this means is that by the time students get to fifth-grade, they will not only have gaps in learning science, they will lack the skills and conceptual understanding needed to succeed on the statewide science exam in their final year of elementary school. While these challenges do exist, there are several online resources that have been created to help close the gap between what is being taught through the old curriculum and what is expected in the new NGSS. Few teachers are aware of these resources nor are they familiar with the concept of student-centered instruction in the classroom to implement such curricula.

Statement of the Problem and Research Questions

With more U.S. jobs in STEM related fields, it is critical that teachers shift the way science is being taught to match this change in the workforce. This shift has been seen with the new Next Generation Science Standards. Students are not asked “to know” content anymore, but to observe, study, question, and deeply grasp scientific concepts. This study examines one teacher's transition from the previous California Content Standards to the NGSS within the context of a fourth-grade classroom. The challenge of teaching with a student-centered approach of instruction is that students come to fourth-grade with little to no experiences in hands-on student-centered instruction in science. In order to help meet this challenge, the following research questions were investigated in this study:

1. What are the effects of implementing student-centered science instruction on student achievement in fourth-grade students?
2. How does the use of student science notebooks impact conceptual understanding, general interest in, and student summative assessment scores in science?
3. In what ways does implementing student-centered science instruction impact student motivation to learn science?
4. How does implementing student-centered science instruction impact student engagement in learning science?

Chapter Summary

In this study, a teacher researcher who was in her third year of teaching fourth-grade conducted this research project on her science teaching experiences during her second and thirds years. Her first year experience in teaching science was with a teacher-centered approach. Because it was her first year as a new teacher, it was easiest for her to follow what experienced teachers recommended. In her second year of teaching, she began transitioning to a more student-centered approach to teaching science with the hope that her students would become critical thinkers and problem solvers. In her third year of teaching, the teacher completely transitioned from a teacher-centered to a student-centered approach to teaching science. The more the teacher familiarized herself with the content and standards, the easier it became to commit herself to creating a student-centered science classroom.

The research in this study focuses on; (a) student use of science notebooks, (b) student achievement on a summative science test, (c) student motivation, and (d) student engagement with the fourth-grade science curriculum. The teacher researcher taught a science unit on Energy and Waves with a student-centered approach and documented evidence by collecting qualitative and quantitative data. Student science related data was collected during the 2017-2018 academic school year and was compared to student science related data in the 2018-2019 academic school year. In addition, the teacher researcher collected data from motivation and engagement observation rubrics during the 2018-2019 academic school year when she completely transitioned from a teacher-centered to a student-centered approach to teaching fourth-grade science.

The next chapter defines the traditional teacher-centered approach to teaching science and discusses why it is necessary to change the way science is taught in order to facilitate deeper-level student understanding in the 21st century. The chapter then goes on to discuss the development of the NGSS out of the Science Framework. Next, the chapter addresses how the California State Science Standards facilitated this practice before the creation of the Next Generation Science Standards (NGSS). Subsequently, the literature review presents student-centered science instruction as a more viable approach to teaching science. Following, the chapter defines what student-centered teaching looks like in a classroom and addresses why teachers should use student-centered instruction in the science classroom. Lastly, the chapter provides a review of various types of student-centered teaching approaches. The literature review in this thesis provides a basis for examining the transformation from teacher-centered to a student-centered approach to science teaching in the 21^{st} century.

CHAPTER II: LITERATURE REVIEW

The traditional or direct instruction approach to teaching dates back to the beginning of teaching itself. From a traditional or direct instruction perspective, it is the teacher's job to establish goals and objectives for students (Brush & Saye, 2001). In a direct instruction approach, students' put all their focus on the teacher—the teacher takes the center stage and the teacher talks while students exclusively listen. During lessons, students rely on their teacher in what, when, and how they are learning (Zakaria & Iksan 2007). Therefore, the teacher completely controls the exact nature of the way the curriculum is presented to her or his students. With direct instruction, the teacher sets specific learning objectives and plans activities designed to meet those objectives (Pederson & Liu, 2003). In this type of classroom, students rely on the teacher to guide them through the step-by-step process in which they are learning. With challenges that arise, it is the teacher's responsibility to resolve any difficulties a student may have. From such an approach, students are not taught to seek out the answers to questions that may arise from curiosity about phenomena in the natural world.

Defining Teacher-Centered Instruction

A traditional or direct instruction approach is synonymous with a teacher-centered approach to teaching science. While a traditional or a direct instructional approach may still be useful in the classroom—especially when teaching subjects like language arts, mathematics, and so forth—it is no longer practical to use this approach exclusively when teaching science. According to the National Center for Educational Statistics (1999), with research on the success of cooperative learning, there has been an increase in the amount of interaction between students during teacher-centered instruction. However, this interaction is guided by the control of the teacher where she or he determines the interactions between the students. Teachers using teacher-centered instruction often determine group membership as well as the interactions between members and even the role each member plays within their group (National Center for Educational Statistics, 1999). With the shift to student-centered instruction, teacher-centered approaches have been criticized for failing to guide students in learning to think critically and problem solve (Hannafin, & Land, 1997). Research also explains how performance deficiencies are attributed to the oversimplified and shallow understanding of a topic (Spiro, Feltovich, Jacobson, & Coulson, 1991). Teachers are often pressured to make sure all content is covered before statewide testing. Therefore, teachers frequently rush through the book with little time to slow down and delve into content in a more meaningful way.

Teacher-centered instruction in the science classroom. Several factors contribute to teachers' resistance to inquiry-oriented pedagogy. A study by Saye and Brush (2004), explains why many teachers do not implement inquiry learning within the science classroom. Teacher's own learning experiences greatly influence the way they structure learning experiences in their classroom. The researchers further describe that those who have a deep understanding, familiarity, and methodology with inquiry education are more likely to engage students with inquiry instruction and those who lack such knowledge impede this practice (Saye & Brush, 2004). Often times, teacher resistance to adopting a student-centered approach to science teaching is rooted in the way they may have been taught science and creates an unwillingness to transition away from teacher-centered instruction. According to research done by Akkus et al. (2007), in a traditional laboratory class, activities are designed by the teacher for students to follow a given set of instructions written on the board or that come from their textbooks. The role of the teacher in a traditional science classroom is to transmit knowledge to students, and students are expected to passively receive the given information (Akkus, 2007). In this style of teaching, students are tested on all information received rather than being tested on true mastery of the content.

McCall (2006), explains that even finding examples in elementary school are often challenging because of teachers' responsibilities in teaching several subjects and pressure to cover the curriculum while maintaining classroom control. Additionally, teachers must prepare students for high-stakes testing while making sure students are meeting standards in subjects that are being tested—reading and mathematics. In school districts where testing is prioritized, science often becomes drilling students to help them prepare for the test rather than the recommended practice of inquiry. Another factor McCall (2006) explains, is that many teachers are weak in preparation of the subject matter. Some teachers believe that textbooks should define curriculum (as cited in McCall, 2006). What this seems to indicate is that teachers put more importance on test preparation of science vocabulary and memorization of facts over teaching students to participate in inquiry-based science activities, lessons, and units that will facilitate deep understanding of the scientific concepts taught. Barton and Levstik (2004), define the traditional teacher-centered approach to teaching in the classroom. In a typical class, much of the twentieth century has had a teacher-centered approach to instruction. This is where there is a focus on covering the textbook material which is supplemented by lectures and the occasional use of films and videos. During discussions, the teacher is predominantly talking and individual seatwork is sometimes differentiated with small group work and tests to measure individual student learning. Interestingly, Barton and Levstik (2004) found that many teachers choose the traditional approach to teaching with the desire of acceptance by both colleagues as well as parents in addition to the pressures of time (Barton & Levstik, 2004). With several outside influences placed on teachers, many seem to comply and please the majority by teaching with a traditional-approach.

A study done in 1999 on the effects of the learning cycle versus traditional text in relation to comprehension, helps to clarify why there has been a shift from the traditional method of teaching science, to a more interactive and hands-on approach (National Center for Educational Statistics, 1999). Science textbooks are generally low in gaining the interests of students. Over two decades ago, research found that science textbooks were traditionally written with defining new terms and exploration examples that followed. Research has shown that science textbooks ended up being mainly used as a dictionary to look up definitions for tests. Research on investigating learning from textbooks found that textbooks often fail to engage students and are detached from their everyday experiences (Driscoll, Moallem, Dick, & Kirby, 1994). Knowing facts about science does not inspire students to become scientists. When the content is not meaningful, students are unengaged and uninterested in learning. It is necessary to step away from a traditional science classroom to facilitate a deeper level understanding that will help them to join a 21^{st} century workforce.

The Old California State Standards for Science

According to the message from the State Board of Education and the State Superintendent of Public Instruction, in 1998, California “adopted academically rigorous content standards in science.” Before the standards were created, California’s State

Board of Education wanted to improve high school graduation rates. The next logical goal was to improve student achievement. It was theorized that developing science standards focused on content that were specific to what "students actually needed to know" and should "be able to do," would help to measure who had mastered the content by the end of each grade. Additionally, the State Board of Education instructed that teachers should use the standards as the foundation for their work rather than as an additional layer. Following the message from the California State Board of Education, the Science Content Standards for California Public Schools: Kindergarten Through Grade Twelve introduced generally what the science content standards were. The standards "included the essential skills and knowledge students would need to be scientifically literate citizens in the 21st century" (California State Board of Education, 1998). The introduction then explained how each grade-level has specific content for kindergarten through grade eight. In elementary school, all sciences were included in each grade. In middle school, they were broken up: sixth grade is earth science, seventh grade focuses on life science, and in eighth grade, physical science. In high school, the standards were divided into content strands: "physics, chemistry, biology/life sciences, and earth sciences." In elementary and middle school, foundational skills and knowledge were to be learned to develop core concepts, principles, and theories at the high school level. Statewide assessments were developed at the time which followed these content standards. Specifically in elementary school, the science content standards introduced science facts and terms and "ask the multiple-subject teacher to find time in the school day for science education." Because of the standards, textbooks and reading materials in science were developed to support students in mastering the standards as well as developing their reading and vocabulary skills. Experiments were expected to create an association between science and the use of their basic mathematical skills (California State Board of Education, 1998, pp. vi-vii). Until recently, these science content standards were meant to prepare a scientifically literate citizenry that were capable of acquiring scientific conceptual knowledge at various grade levels which would prepare them to enter into science and science related fields of study.

The California state standards for science in fourth-grade. In fourth-grade, the previous California State Science Standards were broken up into three units of study: physical sciences, life sciences, and Earth sciences. In physical science, there was a focus on electricity and magnetism. According to the 1998 California Content Standards, students were to know how to design and build both simple series and parallel circuits using wires, batteries, and bulbs. Students were also supposed to know how to build a simple compass and use it to detect magnetic effects within the earth. Fourth-grade students were to understand how currents produce magnetic fields and be able to create a simple electromagnet. Students were also supposed to know that electrically charged objects attract and repel each other and that magnets have two poles (north and south). Students were also required to know that electrical energy can be converted into heat, light, and motion.

In the Life Science unit, a fourth-grade student was supposed to develop a deep understanding that "all organisms need energy and matter to live and grow." Additionally, students were to know that producers and consumers are related to food chains and food webs and how animals often compete with each other for resources. Furthermore, in the fourth-grade standards, students needed to understand that organisms depend on one another for their survival in the environment. Children in fourth-grade also needed to learn about organisms and how they are classified based on living and nonliving components. Also, in this unit, children needed to understand how many plants need animals for pollination and that animals need plants for food and shelter. Finally, in this unit, students were supposed to be aware that most microorganisms do not cause diseases and are beneficial.

The final area of science in the 1998 California Content Standards in fourth-grade was the Earth sciences. In this unit, students needed to have an understanding of the properties of rocks and minerals and the process that forms them. Students were to know the differences between the three types of rocks: igneous, sedimentary, and metamorphic rocks by referring to their properties as well as how they are formed. Regarding the Earth's surface, students were supposed to understand how changes of the Earth come from waves, wind, water, and ice. Students would know that some processes are slow, while some are fast. Also, students needed to know how there are many natural processes which cause rocks to break down into smaller pieces. Finally, fourth-grade students were to understand that moving water reshapes the land by weathering, transposing, and deposition (California State Board of Education, 1998). In all fourth-grade standards, students were supposed to understand or know something in relation to science, rather than being able to explain the content. This type of science learning often times did not allow students to connect the ideas, concepts, and theories to real world phenomena unless the teacher taught in such a way as to allow students to contextualize learning experiences. Rather, science was taught by many teachers in drill and kill fashion that merely prepared students for standardized tests that only provided a snapshot of true scientific understanding.

A Framework for New Science Education Standards

Building the framework for K-12 Science Education was the first step in creating a new generation of science standards for a new generation of science learners. The goal of the framework was to ensure that all students would have some sort of appreciation for the wonders of science. From this perspective, students should acquire skills to continue to learn about science outside of school and have the ability to enter careers in science, engineering, and technology if they choose. According to the Board on Science Education (2012), the framework builds on numerous studies that "highlight the power of integrating understanding the ideas of science with engagement in the practices of science and is designed to build on students' proficiency and appreciation for the science of multiple years of school" (National Research Council, 2012, p. x). To keep the United States competitive internationally, a need to improve K-12 science education has become critical with the need for more prepared science, engineering, and technology professionals in the 21st century. The purpose of the conceptual framework was intended as a guide for next steps of developing standards for all students. The framework describes the "major practices, crosscutting concepts, and disciplinary core ideas that all students should be familiar with by the end of high school" and provides an outline of how they should be developed across each grade level. According to the framework, science education is no longer just science. Engineering and technology are featured in addition to physical sciences, life sciences, and Earth and space sciences. The purpose is to understand the "human-built world" and its value in integrating the learning of science, engineering, and technology (National Research Council, 2012). The rationale for integrating the learning of science, engineering, and technology is that these three disciplined ways of knowing are currently impacting our world more than any other way of understanding and are interconnected with societal evolution in nearly every discipline or field of knowledge.

Before a new framework was created, it had been more than fifteen years since science standards had been discussed on a national level. Within the fifteen years, researchers had developed an understanding of how teaching, and learning science should look like in the classroom (National Research Council, 2012). Additionally, with the new Common Core State Standards, the science framework aimed to integrate math and language arts standards into the new science standards. In addition to integrating multiple subjects, the framework aimed to create a curriculum that is built with the assumption that learning is a developmental progression. As students grow older, they will adjust their views in their own explanations about how the world works. Furthermore, the framework focuses on a limited number of core ideas in science and engineering. The purpose is to avoid shallow coverage of topics and allow teachers and students to explore each scientific idea in greater depth. Having less details is intended to give students more time to engage in scientific exploration and argumentation to achieve a more in-depth understanding of the content presented. Another key idea in which the framework was created, was to emphasize that learning about science and engineering involves scientific inquiry and engineering design is key to establishing scientific explanations (National Research Council, 2012). While scientific inquiry has been a part of science education in the U.S. for many years, this is the first time in U.S. history that engineering practices are an integral part of science education standards. Engineering, now more than ever is having myriad impacts on the ways we interact with the world (e.g., the increasing reliance on smartphones, A.I., automation in the workforce, robotics, and so forth). With this new framework for science, it is evident that in order for these improvements in science education to be successful, curriculum, instruction, professional development, and updated assessments are required to align with the framework's vision.

Development of the Next Generation Science Standards (NGSS)

It was in the late 1980s and early 1990s that the term "standards" were brought into the science education community. The purpose of having set science standards was intentioned to set a science learning benchmark for all students in the United States to be able to achieve. The idea was to have clear, consistent and comprehensive science content across the country. On September 4, 2013, the State Board of Education adopted the Next Generation Science Standards for California Public Schools Kindergarten through grade Twelve (California Department of Education, 2018). According to Bybee (2014), the development of the NGSS began in 2010 and was part of a two-step process. The first part, was the development of a *Framework for K-12 Science Education*. This *Framework* was created by a committee of eighteen experts in the science education field. The framework has three parts: (a) practices, (b) core ideas, and (c) crosscutting concepts (Bybee, 2014). The first part, science and engineering practices, describes behaviors scientists and engineers engage in. These are disciplinary practices that are meant to give students opportunities to learn to engage in scientific investigation by learning important exploration skills. The second part, disciplinary core ideas, describe the core ideas in the science disciplines. These core ideas cover key scientific disciplinary knowledge that is learned—through a spiraling curriculum—on a deeper and deeper level as students' progress through their K-12 academic experiences. The third part, crosscutting concepts, describes concepts linking the different domains of science (nextgenscience.org). The crosscutting concepts are designed to create an increasing understanding of the interconnectedness of science as it is in the real-world rather than learning science as a set of discrete conceptual ideas and theories.

State adoption of the NGSS and its three dimensions. The second part of the new standards was a state-led effort. Twenty-six states pledged their commitment to give serious consideration in adopting the NGSS. The standards were written with a team of forty-one writers who created the standards based on the *Framework*. The standards were created through collaboration between states and stakeholders in science, science education, higher education, and even business and industry. These states created a committee to provide feedback on the drafted standards and provided multiple reviews to eventually create the final document published by the National Academic Press (NAP). Before the standards were approved, they were reviewed to evaluate whether the NGSS were consistent with the *Framework* which was used as a basis to develop the structure and content of the standards. According to Bybee (2013), the NGSS follows the *Framework* in which there are three dimensions for how the standards are organized. The first dimension, *Practices,* describes major practices scientists and engineers apply as they investigate and build on ideas about the natural world. Additionally, there are a set of engineering practices or skills which should be used to design and build systems. The key idea of this first dimension is that scientific practices cannot be fully appreciated without directly experiencing the practices themselves. The second dimension, *Crosscutting Concepts*, have application across all domains of science as they solidify many unifying concepts. The cross cutting concepts do "not only consider disciplinary content, but the ideas and practices that cut across the science disciplines" (Bybee, 2013, p. xv). The final dimension, *Disciplinary Core Ideas*, are the details related to a given discipline. The idea is that each grade should focus on a limited set of ideas and practices in science that students should be able to use to evaluate and select reliable sources of information. The purpose of the new standards is that K-12 science education should reflect real world experiences and connections with science. New science standards have created a shift in expectations of how science should be implemented in the classroom.

Shifting the way science is taught with the NGSS. Shifts in teaching practice are required to achieve the goals set by the framework and actualized by the NGSS. According to the invitational Research Symposium on Science Assessment, "tools including new curriculum materials and new assessments will be important supports to help the K-12 system move in these directions, but without a strong focus on aligned professional development, adopting NGSS and providing these resources will not be sufficient" (Reiser, 2013, p. 2). This issue relates directly to science teachers who are still resistant to changing their teaching practices in light of the new NGSS. Teachers are reticent to change the ways they teach science when they believe there are no new science curricula or professional development to support their efforts. Additionally, teachers are not willing, nor should they be required, to put in their own money into supplying inquiry materials needed for a student-centered classroom.

One major teaching shift that will be required to optimize student science understanding from the previous science standards to the NGSS, is the change from knowing facts to explaining phenomena. Students must understand why they are learning about a concept, rather than just merely understanding that it is part of learning science. With this new approach, teachers and textbooks cannot simply present the facts and definitions, but rather help guide students towards developing ideas with evidence (as cited in Reiser, 2013). When students are investigating on their own, teachers are there as a guide for students' learning rather than simply telling them about the phenomena. Teachers are not sitting at their desks grading papers during inquiry lessons, they are walking around and asking guiding questions to help support students' thinking with conceptions as well as misconceptions of scientific phenomena (e.g. Why do you think that is happening?). When students are able to explain in their own words how and why a scientific concept occurs, students are able to understand scientific content on a deeper level. Students can then internalize their understanding of science similarly to how actual practicing scientists and engineers do. Passmore and Svoboa (2012) describe it well when they express that there is a required shift from learning about scientific ideas, to explaining how and why a phenomena occurs (Passmore & Svoboda, 2012). For example, students in fourth-grade do not just learn that a light bulb needs a positive and a negative charge in order to light. In the classroom, students must work together to determine how to light a light bulb when given a light bulb, two wires, and a battery. By exploring what does not work and what does work, students can grasp the concepts on a deeper and more meaningful level. Students may not yet know what a positive and negative charge is, but when students figure out how to light the light bulb, they will learn that each wire must touch each side of the battery to complete the circuit. From there, teachers can introduce the terms positive and negative charge, and closed and opened circuit when describing more about electricity. Students can go on to use their own science experiences in learning how to light a light bulb to understand and interpret the new academic language. This example illustrates a key way science teaching needs to change in 21^{st} century classrooms.

Defining Student-Centered Instruction

In recent decades, there has been a shift from teacher-centered to student-centered instruction. Hannafin and Land (1997) explain that student-centered teaching has "been touted as an alternative to externally-directed instruction" (Hannafin & Land, 1997, p. 168). Student-centered instruction is where the teacher is a guide and the learner takes responsibility of her or his learning as well as decisions about the dimensions of the learning process (Tandogan & Akinoglu, 2006). Unlike a direct instruction approach, student-centered instruction is a teaching approach where classrooms replace lectures with active learning through cooperative group work situations. When used appropriately, student-centered teaching can change how students learn in the ways they seek solutions to problems without complete dependency on the teacher. In contrast to traditional teacher-centered instruction, in student-centered instruction, learners are expected to monitor their own progress to determine whether they are accomplishing their goals rather than waiting for the teacher to decide on curricular goals (Saye & Brush, 2001). Students take more charge of their own learning and the teacher becomes a facilitator in the learning process to help guide students to higher levels of understanding.

This type of learning is sometimes referred to as project-based learning (PBL) where students' curriculum involves the use of technology as well as inquiry-based learning to reach higher standards than the traditional methods of teacher-centered instruction (Overby, 2009). The major shift with student-centered/inquiry-based instruction is that student learning begins after students are confronted with an "ill-structured problem." Students face ill-structured problems, which have unclear goals in social, political, economic, and scientific issues existent in everyday life (Simon, 1973). This way, students know the issue they are learning about with all the information they gather related the goal of solving the problem. In student-centered instruction, "students do not begin learning until they have encountered a problem to solve" (Gallagher, Sher, Stepien, & Workman, 1995, pp. 137-138). An expected outcome for student-centered instruction is to become an effective problem solver in everyday life. Tandogan and Akinoglu (2007) sum up student-centered learning by stating that when students learn to problem solve they are learning how to learn, students are simply learning by doing. The learners take more responsibility for their own learning, and gradually become more independent from their teachers. The outcome is that independent learners will continue to learn their whole lifetime (Tandogan & Akinoglu, 2007). As students become more independent learners, they will be invested in seeking answers and solutions to problems. This independent learning style is key to developing students' ability to enter into the ever-changing workforce of the 21st century.

Student-centered instruction in a science classroom. Student-centered instruction requires a shift in many teachers' pedagogical paradigms as these teaching methods often differ from how they themselves may have learned science. A thoughtprovoking article by Zakaria and Iksan (2007), discussed the current shortcomings in science as well as in math. As explained in their article, an effective way of teaching the science curriculum is to provide students with skills and strategies that help them develop problem solving skills for everyday life problems (Zakaria & Iksan, 2007). As previously mentioned, ill-structured problems are a key element in problem-based learning. Having a realistic problem differs from having a "well-structured problem" that most school textbooks follow. With ill-structured problems, students lack the necessary knowledge to develop a solution or even describe the nature of the problem. With student-centered instruction, there is no single approach to discover a solution to the problem. Moreover, as students explore and acquire new information, the initial problem may be redefined or changed (Gallagher, Sher, Stepien, & Workman, 1995). With student-centered instruction in a science classroom, it is necessary to find practical solutions to real problems. Students must learn to ask and refine their questions through researching, designing investigations, gathering and analyzing data and information in order to draw conclusions and report their findings (Schneider, Krajcik, Markx & Soloway, 2002). Student-centered activities are designed for students to take an active role in their learning. In the science classroom, students address content through inquiry by actually carrying out the investigation themselves rather than being instructed exclusively by the teacher. In this way, students learn to problem-solve and think critically in different ways than they would if they were given the exact parameters of the investigation.

Technology and inquiry based instruction. With the rise of technology in the 21st century, the use of technology should be an integral part of teaching in the science classroom. According to research, technology integration is an important aspect when implementing project-based learning (PBL) in the classroom (as cited in Condliffe, et al., 2017). Research conducted by Bruce and Levin (2001) suggest that technology within the classroom can encourage inquiry, assist with communication, help with creation of teaching products, and facilitating in students' self-expression (Bruce & Levin 2001). Because of the belief that technology can positively impact student learning (during the 2003-2004 school year) the "United States school districts reportedly spent $7.87 billion on technology" (Hew & Brush, 2006, p. 224). Regarding technology implementation in the classroom, there are two levels; low and high use of technology. Low-level use of technology is where students simply use a computer do an Internet search. High-level use is where for example students collect and interpret data for projects. The goal of inquiry-based instruction, is to have high-level use of technology. In science classrooms, there are options such as virtual labs, integration of digital videos, virtual fieldtrips, and imagery to illustrate scientific concepts. Programs have been created where online modules are used to complete some sort of activity pertaining to the lesson discussed in class through problem solving. With proper implementation, technology can greatly help students explore topics in more depth, in an interactive environment that promotes inquiry-based learning (Bull & Bell, 2008). Songer, Lee, and Kam (2001), found that using technology-enhanced instruction correlated with performance gains. Furthermore, it was found that implementing a technology-rich science program generated enthusiasm for learning and helped to develop fluency in technology. Their research concluded that technology encouraged the use of higher-order thinking with questioning concepts as well as sharing outcomes. This is in contrast to traditional methods of teaching such as drill and practice activities (Songer, Lee, & Kam, 2001). It is evident that with the rise in technology use, it is critical that the classroom exemplifies this shift in how learning should be done. Implementing technology is significant for students to be college and career ready in the 21st century.

Types of Student-Centered Science Instruction

Inquiry-based science instruction. Inquiry learning seems to have stemmed from theorists Jean Piaget, Lev Vygotsky, and David Ausubel in their philosophy of learning known as Constructivism (Cakir, 2008). Constructivism is a learning theory where humans construct their own understanding and meaning of the world through experiences (as cited in Yilmaz, 2008). Constructivism is one of the major influences in inquiry-based science education where students are learning through hands-on experiences. Inquiry-based instruction was originally meant to model how scientist learn and discover concepts in a laboratory. As explained by Dewey (1910), the term “inquiry” in a science classroom was first used as a way of teaching science like a scientist, by problem solving through investigations (Dewey, 1910). Rather than being told why a phenomenon occurs, students are witnessing and discovering a concept in class. Inquiry-based instruction can encourage active and engaging learning activities such as “knowledge building, collaborative discussion, problem solving, and hands-on activities” (as cited in Mazur, Brown, & Jacobsen, 2015, p. 2). This type of teaching is where students can construct essential information on their own with minimal guided instruction (Hmelo-Silver, Duncan, & Chinn, 2007). Moreover, it is argued that inquiry-based instruction provides “extensive scaffolding and guidance to facilitate student learning” (Hmelo-Silver, Duncan, & Chinn, 2007, p. 99). Inquiry instruction is the foundation for the NGSS and how it should be implemented in the science classroom. From this perspective, students are active learners while teachers support the learning process as students interact with the science content.

The 5E model of science teaching. Student-centered instruction is sometimes enacted with the 5E Model to teach science in the classroom. The 5E model consists of the following five phases of science instruction: (a) engagement, (b) exploration, (c) explanation, (d) elaboration, and (e) evaluation. Each phase has a specific role that contributes to the teacher's instruction, and students' formulation of specific scientific content (Bybee et al., 2006). The *engagement* phase, is where the teacher assesses and activates students' prior knowledge and helps them to become "engaged" in a new concept where curiosity is promoted. Following is the *exploration* phase. This is where students "explore" through hands-on activities, in which case they use their prior knowledge to generate new ideas as well as exploring unanswered questions they may have. During this point, students are conducting a preliminary investigation which requires them to problem solve during their exploration. The *explanation* phase is where students' engagement and exploration experiences help to provide opportunities to explain their understanding of the specific concept. At this point, teachers may guide students' thought process towards a deeper level of understanding. Teachers can also utilize this phase to clarify student scientific misconceptions regarding the concepts being investigated. Once students understand the concept, teachers *elaborate* by challenging and extending students' conceptual understandings of a specific topic. This usually includes additional activities. The final phase of the 5E model is *evaluation*. Teachers evaluate student progress and assess students understanding and abilities towards the learning objectives for the lesson or unit (Bybee et al., 2006). Assessment in the evaluation phase is often in the form of an authentic assessment that allows students to show and share what they know about the science concepts being investigated. Following the 5E model is a straightforward way to create a student-centered science classroom environment that allows students to interact with science content like young scientists.

Project-based science instruction. The basis of project-based learning (PBL) is to learn how to learn. Rosenfeld and Ben-Hur (2001), define PBL, as a model that involves students performing meaningful tasks and problem-solve while autonomously constructing their own learning. Their work is representative of their own learning and results in realistic student-generated products (Rosenfeld & Ben Hur, 2001). Akinoglu and Tandogan (2007) define PBL as a way of learning where students learn to perform in groups "in the face of real life problems." Students' must become aware of their own abilities and needs to be able to effectively learn (Akinoglu & Tandogan, 2007, p. 72). The project-based learning model is meant to turn the student from a passive learner, to an active learner, where she or he becomes a self-learner as well as problem solver. In PBL, it is the teacher's roll to familiarize learners with new ideas and to support and guide students as they make sense of what they are experiencing while learning. The teacher helps makes sense of what students are curious about or questioning, and interprets ways in which learners understand and make sense of the activities presented in class (Marx, Blumenfeld, Krajcik, & Soloway, 1997). Project-based learning has become a popular way of learning in all subject areas. However, it has become particularly popular in facilitating student science learning as a way for students to take ownership and direction of their scientific understanding. The inquiry process involved in science lends itself nicely to a project-based approach since student projects drive the instruction taking place in the classroom. With PBL science learning, students take control of their research and teachers are there to facilitate the learning process by scaffolding student conceptual development of content as they complete their own science projects.

Chapter Summary

The purpose of the literature review presented in this chapter was to examine teacher-centered instruction within the context of changing science education standards in the U.S. as well as in the state of California. The chapter then went on to describe student-centered science instruction as an alternative approach to science education in an ever-changing society. The chapter presents this shift in the context of the development of a Science Framework that was used to create the Next Generation Science Standards (NGSS). The literature review indicates that it is evident that the quality of science education that teachers provide to students is highly dependent on what teachers do, and how they teach in the classroom. Therefore, if teachers are to adapt their teaching practices to the new science standards then they will be required to shift the ways they teach science in 21st century classrooms. The chapter showed that with the NGSS, science education is moving away from memorization to application and conceptualization. According to the literature reviewed in this chapter, this change in expectations for students seems to be a tremendous influence on how science is to be explored in the classroom.

An evolving 21st century society has created a new style of cooperation in the workforce. For example, in Silicon Valley, new companies have turned to collaborative group thinking, rather than working individually in cubicles. It appears this collaborative style of work is affecting how students are expected to learn in the classroom. Research reviewed in this chapter indicates that implementing student-centered instruction is key to scientific success in a 21st century classroom. There are several studies that suggest that there is a positive correlation with student engagement and achievement with learning science with a hands-on approach to learning. Lastly, after carefully defining student-centered instruction, the chapter goes on to articulate various types of student-centered science learning approaches that can be successfully utilized in 21st century classrooms. The next chapter of this thesis provides the "Methodology" drawn upon to collect and analyze student data necessary to answer the research questions of the study regarding the impact of transitioning from teacher-centered to student-centered science instruction.

CHAPTER III: METHODOLOGY

Purpose of the Study

The purpose of this study was to examine how transitioning from teacher-centered to student-centered science instruction in a fourth-grade classroom impacted student achievement, engagement, and motivation in science across two academic years (2017-2018~2018-2019). The study investigated this research topic by seeking to answer four research questions: (a) *What are the effects of implementing student-centered science learning on student achievement in fourth-grade students?* (b) *How does the use of student science notebooks impact conceptual understanding, general interest in, and student summative assessment scores in science?* (c) *In what ways does implementing student-centered science instruction impact student motivation to learn science?* (d) *How does implementing student-centered science instruction impact student engagement in learning science?*

In order to answer the research questions, a mixed method comparative study was devised. Both qualitative (student science notebooks, student motivation and engagement in science observation rubrics) and quantitative (student science notebooks, student summative assessment, student interest in science survey) data and analyses were employed to carry out the study. Academic year 2017-2018 students were compared to 2018-2019 students; one class with the beginning stages of student-centered learning, and a second class, with a completely student-centered approach to instruction. The 2017-2018 students were being taught using the NGSS, but the teacher was transitioning from a teacher-centered approach to the beginning stages of student-centered learning. The 2018-2019 students were also taught using the NGSS with the teacher using a completely student-centered approach to teaching science. The science unit chosen for the study was done so because it was similar to the old California State Standards in Science. Of the three main units in fourth-grade, the Foss curriculum and textbook on *Magnetism and Electricity*, most similarly related to the NGSS unit *Energy and Waves*. A component under investigation was to examine student performance and achievement during, and after the twelve week science unit. Another area of study was to investigate student interest in science through the collection of surveys and student motivation and engagement with the collection of science observation rubrics.

Study Context

This study took place during two academic years (2017-2018~2018-2019) in two fourth-grade classrooms located in a suburban area of Los Angeles. The school is a K-8 span school located in the Northwest district of the Los Angeles Unified School District. The school is a Golden Ribbon school as well as a newly California Distinguished School award after only being open in 2012. The school has a Korean dual language immersion program and receives money from the Korean Consulate. In addition, the school is a pilot school, meaning there is autonomy over budget, staffing, governance, curriculum, assessment, and even the school calendar.

Student Demographic Data

Table 3.1 presents student demographic information for each science class taught. There were 68 students included in the study, all of whom had the teacher/researcher as their fourth-grade teacher of record. 32 students were in the researcher's class for the school year of 2017-2018, and 36 were in the researcher's class for the school year of 2018-2019. Each set of students underwent 100 minutes of instruction per week for the duration of the unit as well as during a trimester which lasted twelve weeks. In the 2017-2018 school year, of the 32 students, 19 were boys, and 13 were girls. In this class, 6 students were identified as gifted, 6 students had Individualized Education Plans (IEPs), and 1 was identified as an English Language Learner (ELL). Additionally, 1 student was new to the school and was previously homeschooled. Of the 32 students, 4 were African American, 3 were Asian, 4 were Hispanic, 5 were Indian, 1 was a Pacific Islander, and 15 were white. In the 2018-2019 school year, of the 36 students, 19 were boys, and 17 were girls. In this class, 15 students were identified as gifted, 11 students had IEPs, and 3 students were identified as ELLs. Additionally, 2 students were new to the school and both came from different private schools. In the 2018-2019 class, 2 students were African American, 7 were Asian, 6 were Hispanic, 3 were Indian, 1 was Pacific Islander, and 17 were white.

Table 3.1.
Student demographic data

Academic Year	**Student Participants**	**Student Gender**	**Student Ethnicity**
2017-2018	N=32 total in class **Student Collected Science Work** N=18	F=13 M=19 F=8 M=10	African American=4 Asian=3 Hispanic=4 Indian=5 Pacific Islander=1 White= 15
2018-2019	N=36 total in class **Student Collected Science Work** N=18	F=17 M=19 F=8 M=10	African American=2 Asian=7 Hispanic=6 Indian=3 Pacific Islander=1 White= 17

Student Collected Science Work

Although there were 32 students during the 2017-2018 school year, and 36 students during the 2017-2018 school year, work from 18 students were collected each year. During the 2017-2018 school year, 18 students gave permission to the teacher/researcher to keep their science folders for research purposes. In the 2018-2019 school year all students gave permission to the teacher/researcher. Therefore, 18 notebooks were randomly selected for comparison as student data in this study.

Science Unit of Study

The unit on Energy and Waves is a twelve week unit which focuses on the Next Generation Science Standards 4-PS3 Energy and 4-PS4 Waves and their Applications in Technologies for Information Transfer. Each Wednesday afternoon, the class engaged in an investigation related to the concept that was the focus for the week. The following day, students responded to critical thinking questions and often watched a video that expanded understanding of the concept. To introduce the science concepts, during the first day, students engaged in an investigation with magnets to associate their knowledge of magnets with electricity for when they worked with circuits. Following the concept of magnets, students completed energy and circuits investigations; there were five activities. First, students investigated different ways to light a light bulb using a wire, a bulb, and a battery. Second, a science activity involved students investigating with a variety of materials to see which ones conduct electricity and which do not. The third activity required students to create a switch using only certain materials provided. Fourth, students built and investigated a series circuit. Fifth, students built and investigated a parallel circuit. A post-test quiz was given after the study on energy and circuits..

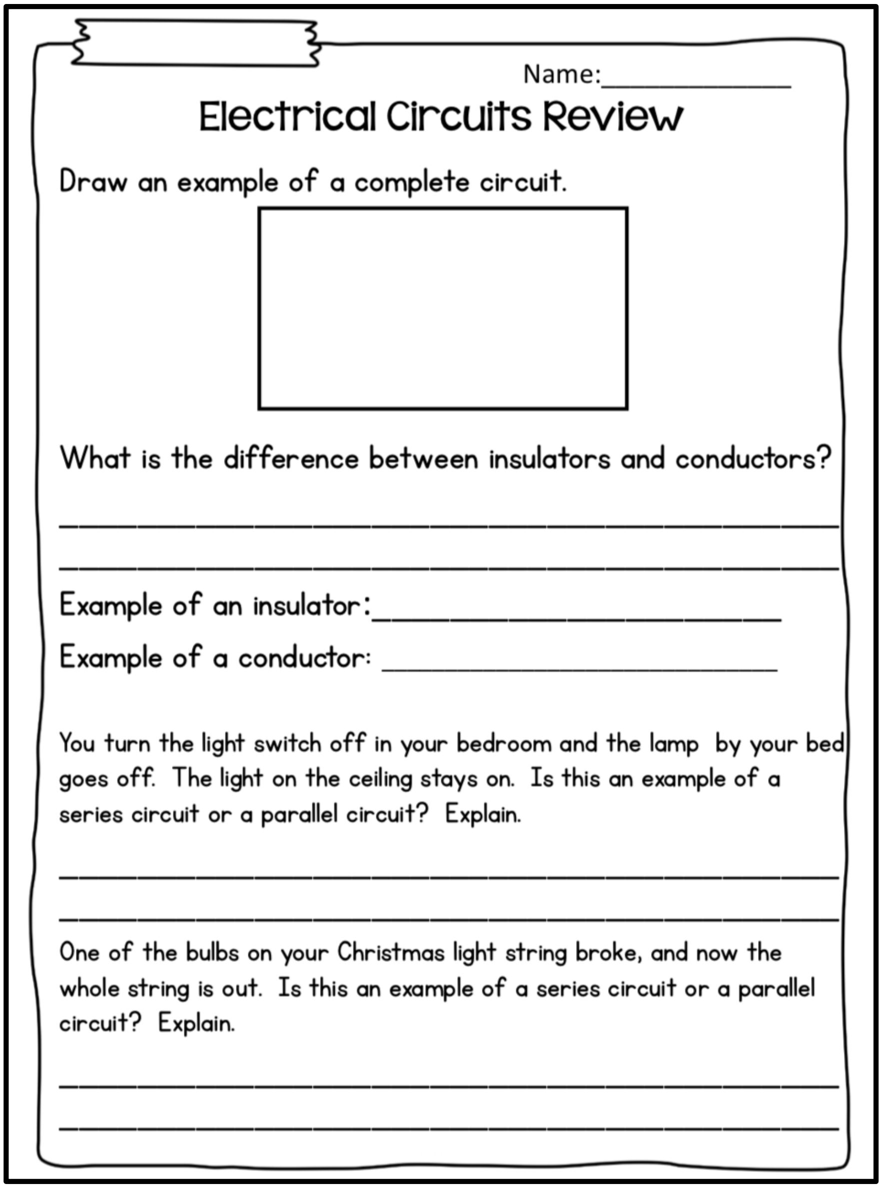
Following energy and circuits, the unit transitioned into sound and light. There were ten activities in this section. Students created a simple straw oboe to investigate vibrations and sound. Afterwards, students read about waves and created waves using jump ropes to show specific amplitudes and frequencies. In the next activity, students made a simple kazoo and experiment with sound. Following, students created pan pipes out of straws. This led into an informational reading passage, diagram, and questions designed to explain how human ears process sound. At the end of the sound and waves section, a short post quiz was completed to check for mastery in the subject area.

In the light activities, students first investigated reflection of light using a mirror. Then students discovered how light travels by discovering which materials are opaque, translucent, and transparent. Following, students investigated how light appears to "bend" as it enters different mediums such as water. To observe the visible spectrums, students saw rainbows on a CD to learn about the visible spectrum. To wrap up the area of study on light, students learned how humans eyes process light through an informational reading passage and diagram. At the end of this area of study, students completed a short quiz on light.

Student Data Collected

Data in this study was collected across two academic school years. During the 2017-2018 academic school year, the following data were collected: (a) student science notebooks, (b) a summative assessment on the unit—Energy and Waves, and (c) a student interest in science survey. During the 2018-2019 academic year, the following data were collected: (a) student science notebooks, (b) a summative assessment on the unit–Energy and Waves, (c) a student interest in science survey, and (d) student motivation and engagement in science observation rubrics.

Student science notebooks. The student science notebooks were organized to follow and build on each activity week-by-week. In this type of organization, students knew that there was a specific place to complete their work for each weekly investigation. The first page was a title page for students to put their names. The following page was the first activity, understanding magnets, in preparation for the content being covered in the unit. The first section of their notebook was electricity and circuits. Each of the five activities were organized to build upon one another. The investigations were titled: *Light it Up, Insulators and Conductors, Switch it On—Switch it Off, All in a Row, and Side by Side*. At the end of the electricity section, students completed a quiz covering the main points of each investigation. The next section of the notebook covered sound waves. There were six investigations to cover sound. The investigations were titled: *Good Vibrations, Waves, Making Waves, What's That Sound, Pan Pipes, and How Do Our Ears Hear?* The final area of study within this unit was studying light. There were five investigations that went with the unit: *Mirror Mirror on the Wall, How Does Light Travel?, Light Moves, Visible Spectrum, and How Do Eyes See?* All notebooks were copied with each sheet that goes with the investigation for students to have ready to go for the entirety of the unit. Pages were graded bi-monthly to review students ideas and misconceptions of a topic. Figure 3.1 provides an example of one of the activity sheets that students were required to complete which allowed students to describe and draw depictions of their understanding about electricity.



Name:______________

Electrical Circuits Review

Draw an example of a complete circuit.

What is the difference between insulators and conductors?

____

____

Example of an insulator:__________________________

Example of a conductor: __________________________

You turn the light switch off in your bedroom and the lamp by your bed goes off. The light on the ceiling stays on. Is this an example of a series circuit or a parallel circuit? Explain.

____

____

One of the bulbs on your Christmas light string broke, and now the whole string is out. Is this an example of a series circuit or a parallel circuit? Explain.

____

____

Figure 3.1. Example page in science notebook

Student summative science test. A summative test in science was given at the end of the unit to measure student achievement on the content matter. The test was broken up in four parts: (a) vocabulary matching, (b) multiple choice, (c) short answer responses, and (d) a conceptual drawing. The first twelve questions were matching for the vocabulary words; amplitude, closed circuit, conductor, cochlea, frequency, insulator, opaque, open circuit, parallel circuit, refraction, series circuit, and wavelength. The next six questions were multiple choice. The questions were: 1) Aluminum foil is an example of a(n) ___. 2) The lights in your house are an example of a ___. 3) Sound is caused by ___ that make waves. 4) The bigger the ___ the louder the sound. 5) In addition to hearing, ears are responsible for ___. 6) ___ in the form of sound waves enter the ear canal and then travel down the canal and run into the eardrum. The next section of the test was short answer. The three questions students needed to respond in complete sentences were: 1) What causes magnets to attract to each other? What causes magnets to repel from each other? 2) What happens when you disconnect a bulb from a series circuit? Explain. 3) Which part of the eye communicates with the brain? What does your brain do with these messages? The last portion of the test was a student drawing. Students needed to draw a wave with high frequency. Figure 3.2 indicates an example of a set of the types of short answer written and drawn responses that students were required to provide on the summative assessment.

Short Answer

19. What causes magnets to attract to each other? What causes magnets to repel from each other?

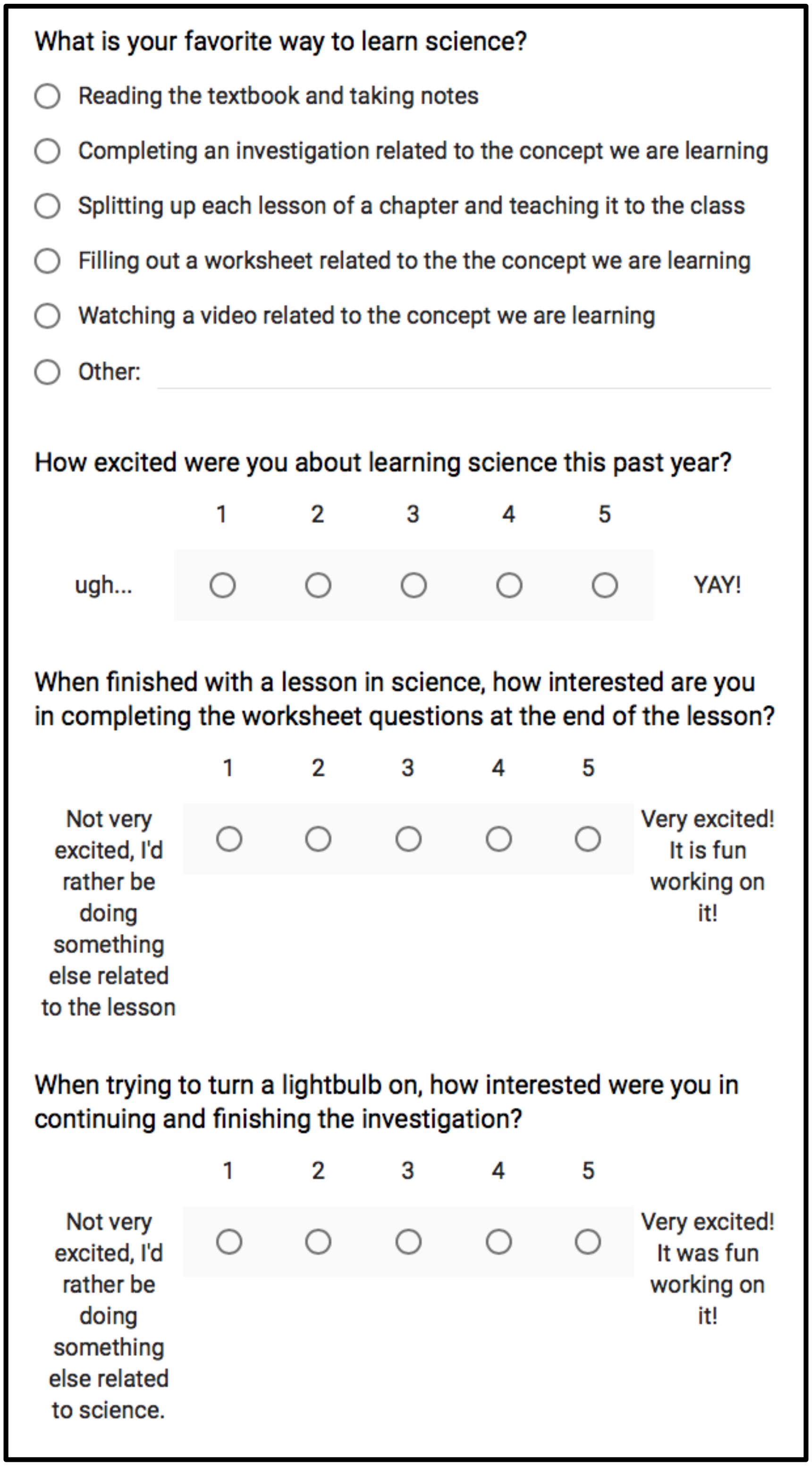
20. What happens when you disconnect a bulb from a series circuit? Explain.

21. Which part of the eye communicates with the brain? What does your brain do with these messages?

22. In the space below, draw a wave with a high frequency.

Figure 3.2. Example of short answer questions in summative test

Student interest in science survey. Before the beginning of the unit, a survey was sent out to the students to complete via Google Forms. The purpose of the survey was to collect data on students' general interest in science, and what aspect of learning science they enjoyed best. There were a total of eight questions for students to answer anonymously. The first question asked whether the student was a girl, boy, or prefer not to say. Following, it asked, “of these subjects, which is your favorite?” The options include math, social studies, science, and language arts. The next question was a short answer and asked students to share why that subject was their favorite in school. Afterwards, they were asked which was “your favorite way to learn science?” The possible options to choose from were: *reading the textbook and taking notes related to the topic*, *filling out a worksheet related to the topic, completing an investigation related to the topic, watching a video related to the topic, read the textbook and have the teacher explain it, or splitting up the lesson and explaining it to the class.* From there, the last three questions were questions on a Likert scale from 1-5, 1 *being not very excited* to 5 *being very excited*. The first of the three questions asked, “How excited were you about learning science this year?” The next question stated, “When finished with a lesson in science, how interested are you in completing the answers at the end of the lesson?” Lastly, students were asked, “When trying to turn a lightbulb on, how interested were you in continuing and finishing your investigation?” The final question, was added the second year the survey was used. It asked students to share any other information related to one's experience with learning science. During both school years, the survey was administered after the first science investigation was completed as some students may have never experienced what a science investigation was until fourth-grade. Figure 3.3 provides an example of some of the survey questions that were posed to students to gain insight into their general interest in science.



What is your favorite way to learn science?

- Reading the textbook and taking notes
- Completing an investigation related to the concept we are learning
- Splitting up each lesson of a chapter and teaching it to the class
- Filling out a worksheet related to the the concept we are learning
- Watching a video related to the concept we are learning
- Other:

How excited were you about learning science this past year?

	1	2	3	4	5	
ugh...	○	○	○	○	○	YAY!

When finished with a lesson in science, how interested are you in completing the worksheet questions at the end of the lesson?

	1	2	3	4	5	
Not very excited, I'd rather be doing something else related to the lesson	○	○	○	○	○	Very excited! It is fun working on it!

When trying to turn a lightbulb on, how interested were you in continuing and finishing the investigation?

	1	2	3	4	5	
Not very excited, I'd rather be doing something else related to science.	○	○	○	○	○	Very excited! It was fun working on it!

Figure 3.3. Sample questions from the student interest survey

During the 2018-2019 school year, to measure student engagement and student motivation, two rubrics were added during science investigations. These rubrics were developed in the second year of the study as the teacher/researcher wanted to better understand student engagement and motivation to learn science during student-centered science teaching. Figures 3.4 and 3.5 each provide examples of the rubrics developed by the teacher/research in order to measure student engagement with and motivation towards doing science.

Student interest in science rubric: motivation. To measure student motivation, another rubric was used. During the investigation, the teacher was looking at how persistent each student was in completing their investigation. Throughout the lesson, the teacher was looking at how motivated students were in posing questions from findings during their work. Additionally, the teacher looked for how students communicated a reasonable and logical argument in their completion of the investigation.

Motivation	Above and Beyond	Right There	Not There Yet
Student Investigation Interaction	Student is persistent in completing investigation.	Student is somewhat persistent in completing investigation.	Student does not complete investigation and gives up.
Student Questioning	Student is motivated to pose questions on their own during investigation.	Student is prompted to come up with a question during investigation.	Teacher provides question during investigation.
Student Communication	Student formulates own reasonable and logical argument during investigation.	Student formulates reasonable argument during investigation.	Student does not form any sort of argument during investigation.

Figure 3.4. Student interest in science motivation rubric

Student interest in science rubric: engagement. To measure student engagement, the teacher looked at whether or not each student was collaborating with their group members during the investigation. The teacher looked at the completeness of the data sheets as they were completing their investigation. Additionally, the teacher was listening to student questioning as well as how well they were able to communicate their findings.

Engagement	Above and Beyond	Right There	Not There Yet
Collaboration	Student collaborates with group members during investigation.	Student somewhat collaborates with group members during investigation.	Student does not collaborate with group members during investigation.
Data Sheets	Student completes data sheet during investigation.	Student somewhat completes data sheet during investigation.	Student does not complete data sheet during investigation.
Student Science Questioning	Student poses questions on their own during investigation.	Student requires minor scaffolding in posing questions during investigation.	Student answers teacher questions during investigation.
Student Communication	Student actively communicates findings.	Student somewhat communicates findings.	Student does not communicate findings.

Figure 3.5. Student interest in science engagement rubric

Data Analysis Organization

The data analysis for this thesis is organized in a manner that systematically follows the organization applied during the data collection phase of this study. Once student science data was collected, the data was catalogued and analyzed in order to better understand some of the ways that students were able to learn the science content taught across the Energy and Waves unit. The data analysis carried out in this study examined: (a) student science notebooks, (b) student summative assessments, (c) student science interest surveys, and (d) student science motivation and engagement rubrics collected in year 2018-1019.

Student science notebook data. Student science notebooks were analyzed in two ways. First an average score was calculated using the total number of points earned divided by the total number of possible points on each activity page. Secondly, descriptive notes were written for each student science notebook indicating the thoroughness of the notebook answers written and accurateness of student science responses and scientific drawings. These notes were then analyzed using textual analysis in order to identify thematic patterns indicating varying levels of scientific conceptual understanding in students' written responses and drawn science depictions. Once these thematic textual responses were identified, they were then interpreted as one indicator of student science achievement.

Student summative assessment in science data. Summative assessments were also analyzed in two ways. First, an average score was calculated using the total number of points earned divided by the total number of possible points on the exam. Secondly, descriptive notes were written from each student's test to interpret the accurateness of student responses. The test was broken up into four sections—vocabulary, multiple choice, short answer, and a drawing. Test results were examined within the context of overall student science conceptual understanding and were utilized as an additional indicator of student science achievement.

Student interest in science survey data. Student interest in science surveys were analyzed based on percentages of responses to each question. Responses indicating explanations of why students choose science as their favorite subject were identified.

Data from the 2017-2018 and 2018-2019 were compared to detect any patterns and changes in student general interest towards science between the academic years.

Student motivation and engagement rubrics data. Student motivation and engagement rubrics were scored on a three point scale—above and beyond, right there, and not there yet. During investigations, the rubrics were used to complete teacher observations by listening and monitoring student motivation and engagement during science activities and lessons. Each rubric was utilized as an informal assessment of student motivation towards and engagement with science content. At any given time during science teaching, the teacher went from table to table, and marked each student measuring both motivation and engagement on the two separate rubrics. Motivation and engagement rubrics were only collected during the 2018-2019 academic year when they were created.

Chapter Summary

This chapter presents the methodology used in this science education research study. Throughout the study, data was collected to examine the impact of transitioning from teacher-centered to student-centered science teaching on student achievement, engagement, and motivation in science during two academic years in a fourth-grade classroom. The chapter provided a description of the context in which the study took place as well as student demographic data from both academic school years (2017-2018 and 2018-2019) during which student data were collected. The chapter then went on to present the types and nature of student science work collected during the two school years and carefully described the science unit of study taught during the data collection phase. Next, this chapter provided a carefully articulated description of each type of data collected during this research. Finally, the chapter explained the organization of the data analysis carried out in this study. The next chapter presents the results of the data analysis conducted in this research study.

CHAPTER IV: RESULTS

The results in this chapter are organized to present findings related to the research questions posed. The chapter results follow the same logic applied to the data collection and analysis sections of this thesis. Results from the analysis are presented by each academic school year and were systematically compared to one another. The data collected examined the effects of implementing student-centered science instruction on student achievement in fourth-grade students. In so doing, student science notebooks were analyzed in order to understand the impact that the use of these notebooks had on student conceptual understanding. Student general interest in science and students' summative assessment scores in science were also examined and the results are presented. All data was collected for both 2017-2018 and 2018-2019 academic school years. During the 2018-2019 academic year, additional data regarding student motivation and engagement in science were collected and analyzed using student engagement and student motivation rubrics during investigation activities.

The results of this research study are presented in the following manner. First, student science achievement was analyzed in the context of the thoroughness of their science notebooks. Student written explanations of science concepts were analyzed to reveal varying degrees of student conceptual understanding. The thematic findings of the science notebooks were then compared across academic years to evaluate the differences in student conceptual understanding during the teacher/research transition to a completely student-centered science instructional approach. Next, student notebook scores were calculated and a percentage score was indicated. Afterwards, student achievement scores resulting from the science unit were analyzed on the summative test on Energy and

Waves. An overall score was calculated and a percentage resulted from both the notebook and summative test analyses. Tables by academic year (2017-2018 and 2018-2019) are provided with student I.D. numbers used to anonymously identify them. Survey results were also analyzed and broken down based on how students responded to each question. Table 4.1. presents the results of initial student notebook and summative science test scores analyses based on student written responses and calculated percentage scores. Thematic results based on the textual analysis conducted of student notebook and summative test is presented after the table.

Table 4.1.
2017-2018 Student Notebook And Summative Test Data

2017-2018 School Year				
Student Number	Student Science Notebook	Notebook Score	Summative Test	Summative Test Score
1	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	62/74=**84%**	● Student accurately defines all science vocabulary words. ● Student answered some of the multiple choice questions correctly. ● Student thoroughly describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	22/25=**88%**
2	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides somewhat accurate drawings of scientific concepts. ● Student completes science investigations correctly.	61/74=**82%**	● Student accurately defines all science vocabulary words. ● Student answered all of the multiple choice questions correctly. ● Student thoroughly describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	25/25=**100%**
3	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations.	70.5/74=**95%**	● Student accurately defines all science vocabulary words. ● Student answered all of the multiple choice questions correctly.	22/5/25=**88%**

	● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.		● Student mostly describes scientific concepts correctly. ● Student somewhat drew an accurate depiction of the concept.	
4	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides somewhat accurate drawings of scientific concepts. ● Student completes science investigations correctly.	65/74=**88%**	● Student accurately defines all science vocabulary words. ● Student answered most of the multiple choice questions correctly. ● Student thoroughly describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	23/25=**92%**
5	● Notebook is thorough in its scientific explanations and concepts. ● Student uses some scientific vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	68/74=**92%**	● Student defines most science vocabulary words. ● Student answered all the multiple choice questions correctly. ● Student somewhat describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	19/25=**76%**
6	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student sometimes uses scientific vocabulary in their explanations. ● Student rarely uses scientific interpretations and evidence to support their answers. ● Student provides accurate drawing of scientific concepts. ● Student mostly completes science investigations correctly.	50.5/74=**68%**	● Student somewhat defines science vocabulary words. ● Student answers some of the multiple choice questions correctly. ● Student somewhat describes scientific concepts. ● Student accurately drew a depiction of the concept.	15/25=**60%**
7	● Notebook is not thorough in its scientific explanations of concepts. ● Student rarely uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student rarely drew accurate depictions of scientific concepts. ● Student somewhat completes science investigations correctly.	55.5/74=**75%**	● Student does not define most science vocabulary words. ● Student answers some of the multiple choice questions correctly. ● Student does not describe scientific concepts correctly. ● Student accurately did not draw an accurate a depiction of the concept.	7/25=**28%**

8	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	72/74=**96%**	• Student accurately defines all science vocabulary words. • Student answered most of the multiple choice questions correctly. • Student thoroughly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	24/25=**96%**
9	• Notebook is not thorough in its scientific explanations of concepts. • Student rarely uses scientific vocabulary in their explanations. • Student scientific interpretations sometimes use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student somewhat completes science investigations correctly.	49/74=**66%**	• Student defines most science vocabulary words. • Student answers some multiple choice questions correctly. • Student does not describe most scientific concepts correctly. • Student did not draw an accurate depiction of the concept.	12/25=**48%**
10	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	64/74=**86%**	• Student accurately defines all science vocabulary words. • Student answered most of the multiple choice questions correctly. • Student mostly describes scientific concepts correctly. • Student somewhat drew an accurate depiction of the concept.	23.5/25=**94%**
11	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	66/74=**89%**	• Student accurately defines all science vocabulary words. • Student answered all of the multiple choice questions correctly. • Student mostly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	23/25=**92%**
12	• Notebook is mostly thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate	59/74=**80%**	• Student accurately defines all science vocabulary words. • Student answered some of the multiple choice questions correctly. • Student mostly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	21/25=**84%**

	drawings of scientific concepts. ● Student completes science investigations correctly.			
13	● Notebook is not thorough in its scientific explanations of concepts. ● Student rarely uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student rarely drew accurate drawings of scientific concepts. ● Student somewhat completes science investigations correctly.	55.5/74=**75%**	● Student does not define most science vocabulary words. ● Student does not answer any multiple choice questions correctly. ● Student does not describe most scientific concepts correctly. ● Student accurately drew a depiction of the concept.	4/25=**16%**
14	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student uses some scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides accurate drawing of scientific concepts. ● Student completes science investigations correctly.	49.5/74=**67%**	● Student defines most science vocabulary words. ● Student answered most multiple choice questions correctly. ● Student describes most scientific concepts correctly. ● Student accurately drew a depiction of the concept.	18/25=**72%**
15	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student mostly completes science investigations correctly.	54/74=**73%**	● Student defines some science vocabulary words. ● Student answered some multiple choice questions correctly. ● Student did not describe scientific concepts correctly. ● Student accurately drew a depiction of the concept.	11.5/25=**46%**
16	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	66/74=**89%**	● Student defines some science vocabulary words. ● Student answered most multiple choice questions correctly. ● Student did not describe scientific concepts correctly. ● Student accurately drew a depiction of the concept.	12/25=**48%**
17	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student sometimes uses scientific vocabulary in their explanations.	52.5/74=**70%**	● Student defines few science vocabulary words. ● Student answered some multiple choice questions correctly. ● Student somewhat describes	12/25=**48%**

	• Student scientific interpretations sometimes use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.		scientific concepts correctly. • Student did not accurately draw a depiction of the concept.	
18	• Notebook is somewhat thorough in its scientific explanations of concepts. • Student sometimes uses scientific vocabulary in their explanations. • Student scientific interpretations rarely use evidence to support their answers. • Student sometimes provides accurate drawing of scientific concepts. • Student somewhat completes science investigations correctly.	48.5/74=**66%**	• Missing	Missing

Table 4.2
2018-2019 Student Notebook And Summative Test Data

2018-2019 School Year				
Student ID	Student Science Notebook	Notebook Score	Summative Test	Summative Test Score
1	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	83/84=**98%**	• Student accurately defines all science vocabulary words. • Student answered all of the multiple choice questions correctly. • Student thoroughly describes scientific concepts correctly. • Student did not draw an accurate depiction of the concept.	24/25=**96%**
2	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	84/84=**100%**	• Student accurately defines all science vocabulary words. • Student answered most of the multiple choice questions correctly. • Student thoroughly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	24/25=**96%**

3	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations sometimes use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	70.5/74=**95%**	• Student accurately defines all science vocabulary words. • Student answered all of the multiple choice questions correctly. • Student mostly describes scientific concepts correctly. • Student somewhat drew an accurate depiction of the concept.	23/25=**92%**
4	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	80/84=**95%**	• Student accurately defines all science vocabulary words. • Student answered all of the multiple choice questions correctly. • Student thoroughly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	25/25=**100%**
5	• Notebook is thorough in its scientific explanations of concepts. • Student sometimes uses scientific vocabulary in their explanations. • Student uses scientific interpretations and evidence to support their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	79.5/84=**94%**	• Student somewhat defines science vocabulary words. • Student answers some of the multiple choice questions correctly. • Student somewhat describes scientific concepts. • Student did not draw an accurate depiction of the concept.	15/25=**60%**
6	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student sometimes uses scientific interpretations and evidence to support of their answers. • Student provides accurate drawings of scientific concepts. • Student completes science investigations correctly.	77.5/84=**92%**	• Student accurately defines all science vocabulary words. • Student answered most of the multiple choice questions correctly. • Student thoroughly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	24/25=**96%**
7	• Notebook is thorough in its scientific explanations of concepts. • Student uses scientific vocabulary in their explanations. • Student scientific interpretations use evidence to support their answers. • Student provides accurate	81/84=**96%**	• Student accurately defines all science vocabulary words. • Student answered most of the multiple choice questions correctly. • Student thoroughly describes scientific concepts correctly. • Student accurately drew a depiction of the concept.	24/25=**96%**

	drawings of scientific concepts. ● Student completes science investigations correctly.			
8	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student sometimes uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	68/84=**80%**	● Student defines some science vocabulary words. ● Student answered some of the multiple choice questions correctly. ● Student describes some scientific concepts correctly. ● Student accurately drew a depiction of the concept.	15/25=**60%**
9	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student sometimes uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student did not accurately draw scientific concepts. ● Student completes science investigations correctly.	68.5/84=**82%**	● Student defines most science vocabulary words. ● Student answered most of the multiple choice questions correctly. ● Student describes most scientific concepts correctly. ● Student did not accurately draw a depiction of the concept.	20/25=**80%**
10	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	70.5/84=**94%**	● Student defines most science vocabulary words. ● Student answered most of the multiple choice questions correctly. ● Student mostly describes scientific concepts correctly. ● Student drew an accurate depiction of the concept.	21/25=**84%**
11	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student somewhat provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	74/84=**88%**	● Student defines most science vocabulary words. ● Student answered most of the multiple choice questions correctly. ● Student thoroughly describes scientific concepts correctly. ● Student did not draw an accurate depiction of the concept.	20/25=**80%**
12	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific	79/84=**94%**	● Student accurately defines all science vocabulary words. ● Student answered most of the multiple choice questions	24/25=**96%**

	vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.		correctly. ● Student thoroughly describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	
13	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	78.5/84=**93%**	● Student accurately defines all science vocabulary words. ● Student answered most of the multiple choice questions correctly. ● Student thoroughly describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	22/25=**88%**
14	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	82/84=**97%**	● Student accurately defines all science vocabulary words. ● Student answered all of the multiple choice questions correctly. ● Student thoroughly describes scientific concepts correctly. ● Student accurately drew a depiction of the concept.	25/25=**100%**
15	● Notebook is thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student scientific interpretations use evidence to support their answers. ● Student sometimes provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	81/84=**96%**	● Student accurately defines all science vocabulary words. ● Student answered most of the multiple choice questions correctly. ● Student thoroughly describes most scientific concepts correctly. ● Student accurately drew a depiction of the concept.	24/25=**96%**
16	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student does not use scientific vocabulary in their explanations. ● Student scientific interpretations sometimes use evidence to support their answers. ● Student sometimes provides accurate drawing of scientific concepts. ● Student sometimes completes	58.5/84=**69%**	● Student defines some science vocabulary words. ● Student answered some multiple choice questions correctly. ● Student somewhat describes scientific concepts correctly. ● Student did not accurately draw a depiction of the concept.	15/25=**60%**

	science investigations correctly.			
17	● Notebook is somewhat thorough in its scientific explanations of concepts. ● Student uses scientific vocabulary in their explanations. ● Student sometimes uses scientific interpretations sometimes use evidence to support their answers. ● Student sometimes provides accurate drawings of scientific concepts. ● Student completes science investigations correctly.	71.5/84=**85%**	● Student defines most science vocabulary words. ● Student answered most multiple choice questions correctly. ● Student somewhat describes scientific concepts correctly. ● Student did not accurately draw a depiction of the concept.	18/25=**72%**
18	● Notebook is not thorough in its scientific explanations of concepts. ● Student rarely uses scientific vocabulary in their explanations. ● Student scientific interpretations rarely use evidence to support their answers. ● Student does not provide accurate drawings of scientific concepts. ● Student does not completes science investigations correctly. ● Student was absent for 2 weeks and missed a lot of science instruction/investigation	37/84=**44%**	● Student defines some science vocabulary words. ● Student answered most multiple choice questions correctly. ● Student somewhat describes scientific concepts correctly. ● Student did not accurately draw a depiction of the concept.	16.5/25=**66%**

Student Science Notebooks Thematic Results

During both the 2017-2018 and 2018-2019 school years, the same science notebook format was used by the teacher/researcher as both a teaching tool and as a principle data source to see if students' responded with deeper levels of mastery about scientific concepts on energy and waves when a completely student-centered approach to teaching was implemented in the classroom. During data analysis, five different thematic findings resulted from the science notebook examination: (a) scientific explanations, (b) use of scientific vocabulary, (c) use of evidence in scientific interpretations, (d) accuracy of conceptual drawings, and (e) how accurately students completed each science investigation. The 2018-2019 school year was when a completely student-centered approach to learning science was implemented in this fourth-grade classroom. During the 2017-2018 school year, the total amount of points students could possibly earn was 74 points. In the 2018-2019 school year the total points possible was 84 as the teacher/researcher scored certain analysis/comprehension questions worth more points based on her experience from the previous school year.

Scientific explanations. Students thoroughness was broken up into three parts when being analyzed. In their overall notebooks, students showed work that was: (a) very thorough, (b) somewhat thorough, or (c) not thorough based on the depth of understanding students exhibited when explaining scientific concepts. Figure 4.1 indicates the thoroughness in the overall science notebook responses during both the 2017-2018 and 2018-2019 school years.

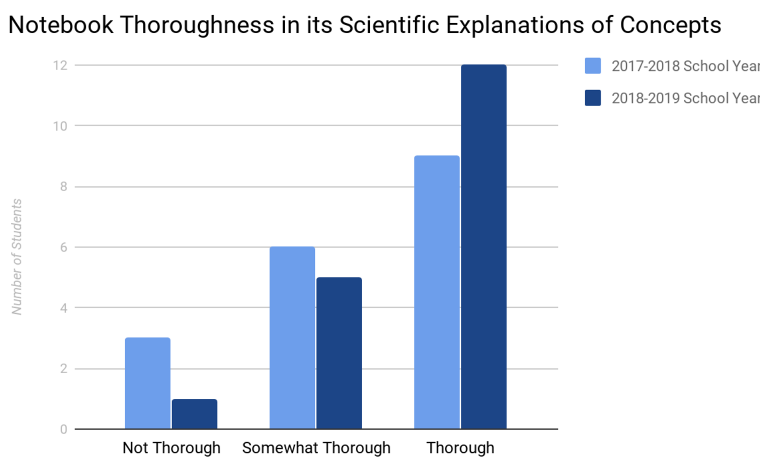


Figure 4.1. Notebook thoroughness in scientific explanations of concepts

Students who were thorough in their work provided more detailed and elaborate descriptions of science concepts compared to those who scored in the somewhat category. In the somewhat category, students often began to explain what was happening, but then could not elaborate nor explain science concepts with detail. Those who were not thorough did not have a clear understanding of the topic at hand and were unable to explain the scientific concept. In the 2017-2018 school year, 50% students were very thorough in their work, 33% of students were somewhat thorough and 17% were not thorough in their scientific explanations. During the 2018-2019 school year, there is a clear shift in student thoroughness in their work. In the 2018-2019 year, 66% of students were very thorough, 27% were somewhat thorough, and 6% were not thorough in their notebook explanations. In the somewhat thorough category, there were 6 % less students during the 2018-2019 year because more students exhibited very thorough work. Only one student during the 2018-2019 school year was not thorough. The likely cause for his work not being thorough was because he was absent for a significant amount of time during the unit. Most students scored thorough in their work as the teacher/researcher taught students how to independently write answers and explain scientific concepts in complete sentences. Those who did not receive full credit were not able to answer the question completely or did not finish answering the question during the allotted time.

Scientific vocabulary. Use of scientific vocabulary was measured based on three categories: (a) the student frequently uses scientific vocabulary, (b) somewhat uses scientific vocabulary, or (c) rarely uses scientific vocabulary during their responses of scientific explanations.

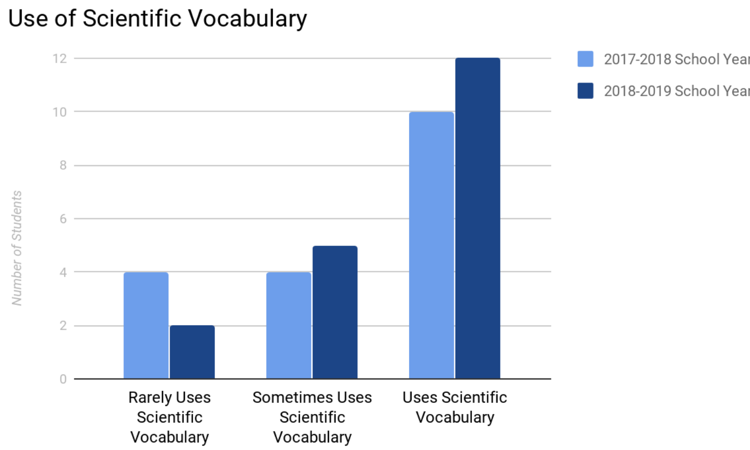


Figure 4.2. Use of scientific vocabulary in notebook

Figure 4.2 indicates the overall use of scientific vocabulary imbedded throughout the notebook during both the 2017-2018 and 2018-2019 school years. From the written textual analysis conducted, it is clear that more students from the 2018-2019 school year had a higher level of facility with scientific vocabulary compared to the previous school year. In the 2018-2019 school year, when a new word was presented during science activities and lessons, the teacher had a student add the word, a definition, and a contextual example of its use onto the class science board. With frequent exposure to the science terminology and concepts, students seemed to grasp the new science terms on a deeper level. Additionally, while having science related conversations, the teacher made sure to reframe student sentences to include the necessary scientific terminology in students' explanations. For example, when a student would respond, *"everything was touching so the lightbulb turned on"*, the teacher would reframe the students sentence by saying, *"what you mean to say is that, the circuit is closed (without a break) it allows the electricity to flow freely which is why the lightbulb turned on."* The teacher/researcher would then made sure the student said it in this way to practice using the proper scientific explanation and academic language needed to be successful. In both years, over 50% of the students scored high in using scientific vocabulary in their science notebooks. In the 2017-2018 school year, 55% of students used scientific vocabulary compared to 66% in 2018-2019 school year. In the 2017-2018, 22% of students sometimes used science vocabulary compared to the 2018-2019 year at 33%. During the 2018-2019 school year, 22% of students rarely uses scientific vocabulary, compared to 11% during the 2018-2019 school year. In order to answer the question, students have been taught to repeat the question in their response which is another reason there was a high level of vocabulary use. Additionally, to fully explain scientific concepts, students were required use scientific terminology when exhibiting comprehension of a scientific topic.

Scientific interpretations. Scientific interpretations were measured by how well students were able to use evidence from scientific resources (the textbook, articles, websites, videos, and investigations) to support their findings about a scientific concept being explored. The use of scientific interpretations were examined using three descriptors: (a) always uses evidence, (b) sometimes uses evidence, and (c) rarely uses evidence.

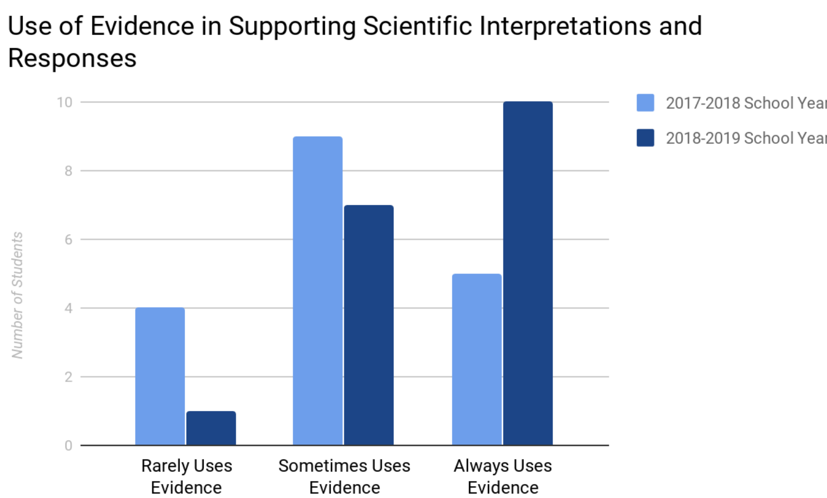


Figure 4.3. Use of evidence in supporting scientific interpretations and responses in notebook

Figure 4.3 illustrates the overall use of evidence in scientific interpretations during both the 2017-2018 and 2018-2019 school years. Results of student use of evidence in supporting scientific interpretations clearly indicate that students had a deeper conceptual understanding of the scientific concepts that were taught in class due to inquiry-based science instruction. In the 2017-2018 school year, content was either taught using a textbook, or semi inquiry-based science instruction where content was covered in the textbook and then explained through a hands-on activity. The data shows a significant shift in the amount of students who used evidence in their scientific interpretations. In the always uses evidence section, the number of students who "always used evidence" doubled. In the 2017-2018 school year, 27% of students always used evidence in their scientific interpretations and responses compared to 55% during the 2018-2019 school year. During the 2017-2018 school year, 50% of students sometimes used evidence compared with 39% during the 2018-2019 school year. In the 2017-2018 school year 22% of students rarely used evidence compared to 5% in the 2018-2019 school year. With the shift from a more traditional approach to a completely student-centered instructional approach which took place during the 2018-2019 academic year, it is evident that utilizing the NGSS to guide student use of evidence to support scientific interpretations in their notebook significantly impacted how students learned science content during inquiry-based science investigations.

Scientific conceptual drawings. Throughout the science notebooks, students used drawings during their investigations to illustrate scientific conceptual understanding.

Drawings were not analyzed on the basis of whether they were artistically drawn or not. Rather, the student drawn scientific depictions were analyzed in relation to how detailed, clear, and accurate students drawings were in their representation of the scientific concepts taught during the unit of study.

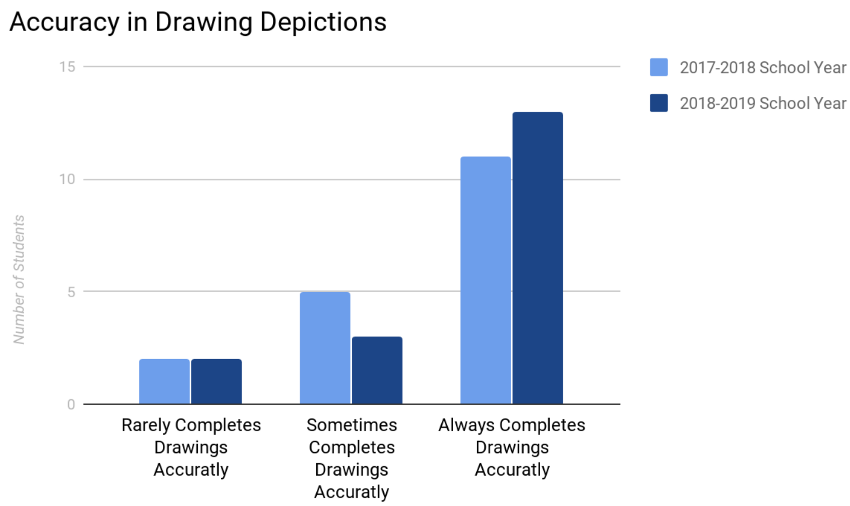


Figure 4.4. Accuracy of drawing depictions in notebook

Figure 4.4 represents how well students accurately drew their depictions of scientific concepts during both the 2017-2018 and 2018-2019 school years. During both years, students scored well on their accuracy of scientific conceptual drawings. In the 2018-2019 year however, results indicate some growth in students' accuracy of conceptual drawings. In the 2017-2018 school year, 61% of students always drew accurate depictions of scientific concepts compared to 72% during the 2018-2018 school year. During the 2017-2018 school year, 28% sometimes drew accurate depictions of scientific concepts compared to 17% in the 2018-2019 school year. During both school years (2017-2018~2018-2019) 11% of students rarely drew accurate depictions of scientific concepts. Textual analysis of student drawings indicates that this may be because students overall showed more thoroughness in their science notebook drawings during the 2018-2019 school year. Many student drawings were representations of student thinking regarding how their investigations proceeded (e.g. what worked and what did not work). Simply drawing a correct parallel circuit did not always mean students had a strong conceptual understanding of how a parallel circuit worked. This is why conceptual drawings were used as one indicator of students' overall scientific understanding.

Scientific investigation completion. The majority of the science notebooks required students to complete the work that went with the science investigation being conducted. In order to show that the investigation were completed correctly, all parts needed to be filled out on the lab sheet to show that the work was completed.

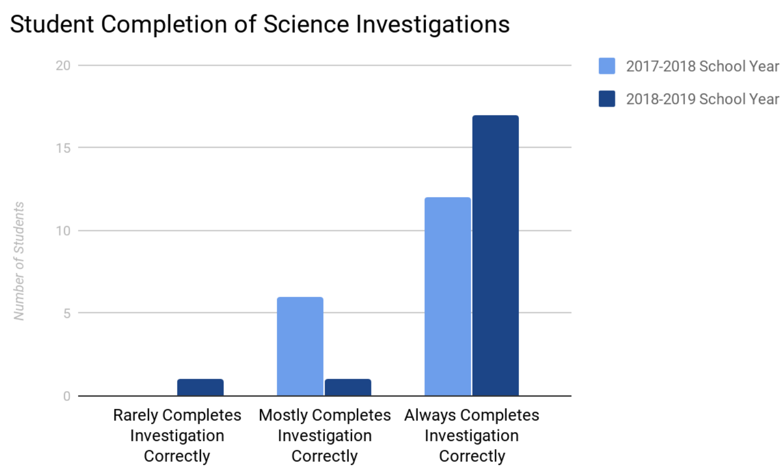


Figure 4.5. Student completion of science investigations in notebook

Figure 4.5 represents how well students completed the science investigations based on their responses in their science notebooks during both the 2017-2018 and 2018-2019 school years. During the 2018-2018 school year, 67% of students always completed investigations correctly compared to 94% in the 2018-2019 school year. In the 2017-2018 school year 33% of students mostly completed investigations correctly compared to 5% in the 2018-2019 school year. No student rarely completed invitations correctly in the 2018-2019 school year compared to 5% in the 2018-2019 school year. Interestingly in the 2017-2018 year, no student showed that they "rarely completed the investigation correctly". The reason there was one student who rarely completed the investigation correctly during the 2018-2019 school year, was because this student was absent for a significant period of time during the unit, and was unable to complete many of the investigations. The reason for most students being able to complete the investigations correctly was likely due to teacher support with reminders as well as group support from their classmates during the activities. The teacher/researcher made sure to explain the task, go over the parameters, and remind students of time constraints. She also made sure to give reminders about the work that needed to be completed in addition to completing the science investigation. The only way students would "rarely complete the science investigation" would be if the student was absent frequently, or if they were off-task instead of completing work. Though students still needed reminders, students were able to work independently, and also enjoy the challenge in wanting to be the first group to complete the task.

Student Science Notebook Achievement Scores

Data to examine academic achievement was also collected from student performance in the class based on an overall score on their science notebook after the unit was completed in both the 2017-2018 and 2018-2019 school year. For the duration of the 12 weeks, a science notebook was completed. Scores were given on each page, with a summative achievement score given at the end of the unit. Figure 4.6 indicates the percentage/letter grades students received on their science notebook each school year.

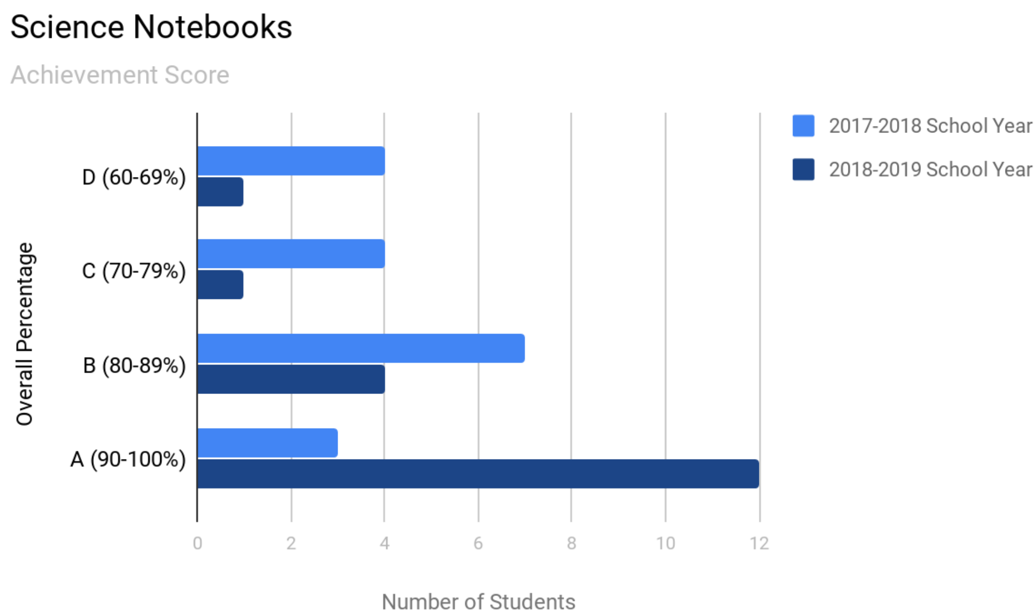


Figure 4.6. Science notebook distribution during the 2017-2018 and 2018-2019 school year

During the 2018-2019 school year, a completely student-centered approach to science teaching was implemented in the fourth-grade classroom. These scores were based on each 18 randomly selected folders from each school year. Overall, the scores indicated a positive shift towards a higher overall percentage of correct answers in the science notebooks. The total number of A's during the 2018-2018 school year was 16% compared to 67% in the 2018-2019 school year. The percent of B's in the 2018-2019 was 39% compared to 22% in the 2018-2019 school year. The number of C's and D's during the 2017-2018 school year was each 22% compared to 5% for each in the 2018-2019 school year. The number of D's and C's during the 2018-2019 school year decreased significantly when a more student-centered approach was implemented in the classroom. All in all, the 2018-2019 class with more student-centered activities demonstrated a positive outcome in their science notebook scores. Students in the 2018-2019 year with A's tripled compared to the 2017-2018 school year. Student notebook grades with B's C's and D's decreased due to the significant amount of A's. When students are more autonomous in their learning, it seems that the students are more willing and wanting to explain their work from their experiences through investigation.

Summative Test

At the end of the energy and waves unit, a summative assessment was given. The teacher/researcher created this assessment based on what was covered during the course of the 12 weeks. The test was broken up into 4 sections: (a) vocabulary, (b) multiple choice, (c) short answer, and (d) a drawing depiction. The vocabulary section had 12 words and definitions that needed to be matched, each worth 1 point towards their grade. Following, there were 6 multiple choice questions each with a, b, c, or d as an answer choice, each worth 1 point. Afterwards, there were 3 short answer questions, each worth 2 points based on completeness and thoroughness in the students' responses. The final part of the test was a blank box for the student to draw a wave with a high frequency. The drawing depiction was worth 1 point towards their final grade. The entire test was scored out of 25 total points possible. Results are reported by each section of the test: vocabulary, multiple choice, short answer, and drawing depiction.

Vocabulary words. There were 12 vocabulary words that needed to be matched to their definitions ranging from electricity, sound, light, and wavelength concepts.

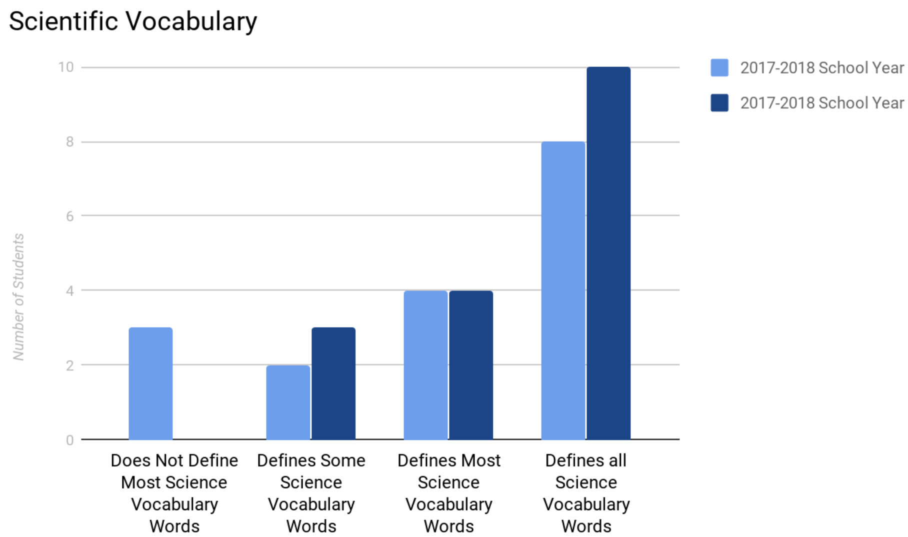


Figure 4.7. Defining scientific vocabulary on summative test

In the 2017-2018 school year, some students actually were unable to define most vocabulary words compared to the 2018-2019 school year with none. This may be because students during the 2017-2018 school year just experienced vocabulary through textbook learning. During the 2018-2019 school year, more students were able to define all science vocabulary words perfectly. In the 2017-2018 school year 44% of students defined all vocabulary words compared to 56% in the 2018-2019 school year. In both the 2017-2018 and 2018-2019 school years, 22% defined most vocabulary words. During the 2017-2018 school year 11% of students defined some vocabulary words compared to 16% in the 2018-2019 school year. In the 2017-2018 school year 16% of students did not define most vocabulary words compared to none in the 2018-2019 school year. Interestingly, the number of students who answered most words correctly showed no change. More students were able to define “some” vocabulary words in the 2018-2019 school year compared the 2017-2018 school year. This could be because no students from the 2018-2019 class were placed in the category of not knowing most vocabulary words. This positive shift seems to indicate that when students learned science concepts through their own experiences, they were able to internalize the scientific concept on a much deeper level than they did from the textbook. Additionally, in the 2018-2019 school year, the teacher had the students create a vocabulary wall, as well as reframing the way they discussed scientific concepts after vocabulary words were introduced.

Multiple choice. In the multiple choice section, there were 6 questions ranging from electricity, sound, light, and wavelength concepts. Each of the 6 questions had 4 possible answers to choose from (a, b, c, or d).

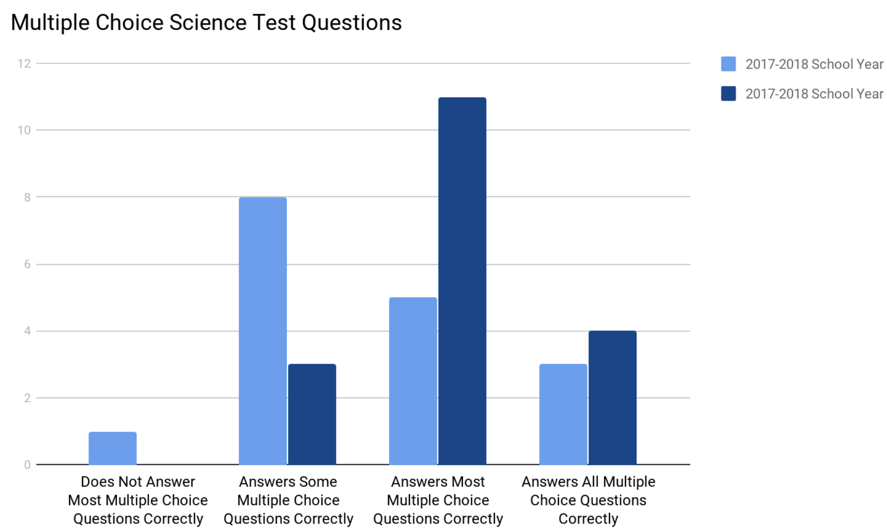


Figure 4.8. Multiple choice questions on summative test

During the 2017-2018 school year, far more students answered “some” multiple choice questions correctly than during the 2018-2019 school year. During the 2017-2018 school year 17% of students answered all multiple choice questions correctly compared to 22% in the 2018-2019 school year. In the 2017-2018 school year, 28% of students answered most multiple choice questions correctly compared to 61% in 2018-2019. In the 2017-2018 school year 44% of students answered some multiple choice questions correctly compared to 17% in 2018-2019 school year. During the 2017-2018 school year, 5% of students did not answer any multiple choice questions correctly compared to no students in the 2018-2018 school year. There was a positive shift in students ability to answer most multiple choice questions correctly during the 2018-2019 school year. This shift indicates students' higher conceptual understanding of the content with a student-centered approach versus the traditional teacher-centered practices. Though there was a shift in students abilities to answer all multiple choice questions correctly in the 2018-2019 school year, it is interesting that there was not a greater difference between the 2017-2018 school year. Most students during the 2018-2019 school year who missed 1 or 2 points often missed a point in the multiple choice category. The reason for why students often did not earn a perfect score in this category could be because of wording of the questions.

Short answer. The short answer responses were the most challenging part of the test, as it required deep comprehension of the topic to answer thoroughly. There were 3 short answer questions each worth 2 points as a students could partially answer the question and still receive 1 point.

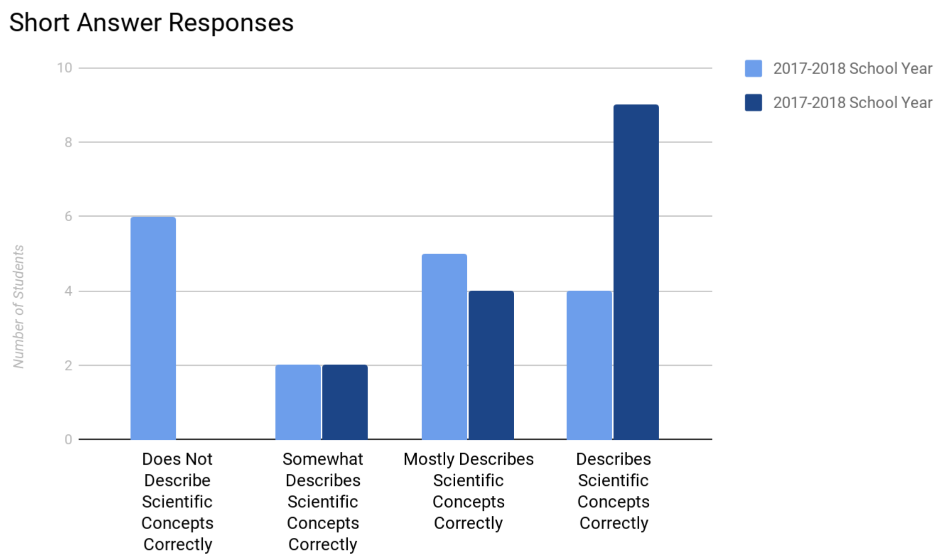


Figure 4.9. Short answer responses on summative test

During the 2017-2018 school year, 6 of the 18 students were not able to describe any of the short answer scientific concepts correctly compared to the 2018-2019 school year where no students were unable to describe the scientific concepts. There is no change in students who somewhat described scientific concepts correctly, and there is one more student who mostly described the scientific concepts correctly in the 2017-2018 school year. During the 2018-2019 year, the amount of students who were able to fully describe the scientific concept correctly more than doubled compared to the 2017-2018 school year. In the 2017-2018 school year, 22% of students described all scientific concepts correct in the short answer responses compared to 50% in the 2018-2019 school year. During the 2017-2018 school year, 28% of students described most scientific concepts correctly compared to 22% in the 2018-2019 school year. During both school years (2017-208 and 2018-2019) 11% of students somewhat described scientific concepts correctly. In the 2017-2018 school year 33% of students did not describe scientific concepts correctly compared with none in the 2018-2019 school year. It is evident that students were able to thoroughly describe the scientific concept because they learned the concept through their own science activities and investigations carried out versus learning the concept from a textbook. Additionally, because students during the 2018-2019 school year, were more thorough in their science notebooks they were able to be more thorough in their short answer responses on the summative test.

Drawing depiction. The drawing depiction was the last part of the test. Student's had to draw a wave with high frequency in the empty box. What the teacher was looking for, were waves tightly squeezed together and a centerline going horizontally to show where to measure for the amplitude.

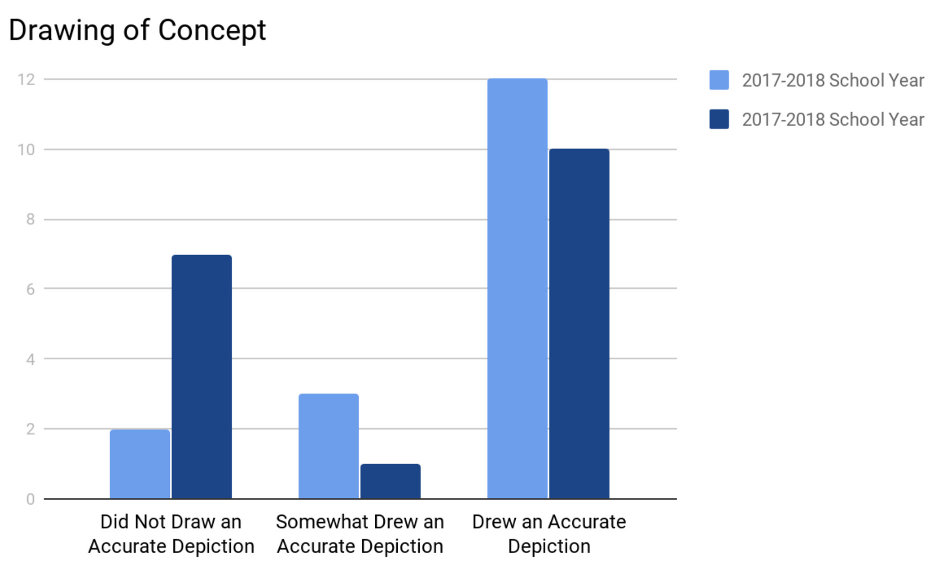


Figure 4.10. Drawing of concept on summative test

Interestingly, more students were unable to accurately draw a depiction of the wave with high frequency in the 2018-2019 school year compared to the 2017-2018 school year. In the 2017-2018 school year 67% of students drew and accurate depiction of the scientific concept compared to 55% in the 2018-2019 school year. In the 2017-2018 school year 16% of students somewhat drew and accurate depiction compared to

5% in the 2018-2019 school year. In 2017-2018 school year, 11% of students did not draw an accurate depiction compared to 39% in the 2018-2019 school year. Because more students were unable to draw an accurate depiction of a wave during the 2018-2019 year, there were less students who were able to draw the high frequency wave accurately. The reason for this may be because students during the 2017-2018 school year saw what waves looked like according to illustrations in a textbook, whereas 2018-2019 students did not. In both school years, students practiced making different types of waves using jump ropes. In the 2017-2018 year, they first read about waves in the textbook, saw different drawings of waves, and then completed the activity. In the 2018-2019 school year, their first experience to waves was during the activity where they made waves with the jump ropes. Following, they watched a video on waves. If the teacher had created a closing activity for students to grasp how to draw waves, there may have been a shift in students' accuracy in their drawn wave depictions.

Summative Test Achievement Scores

Student summative test scores were also used to measure student achievement on the energy and waves science unit. The same 25 point question test was given both 2017-2018 and 2018-2019 school year to analyze student achievement when student-centered instruction was implemented in the classroom.

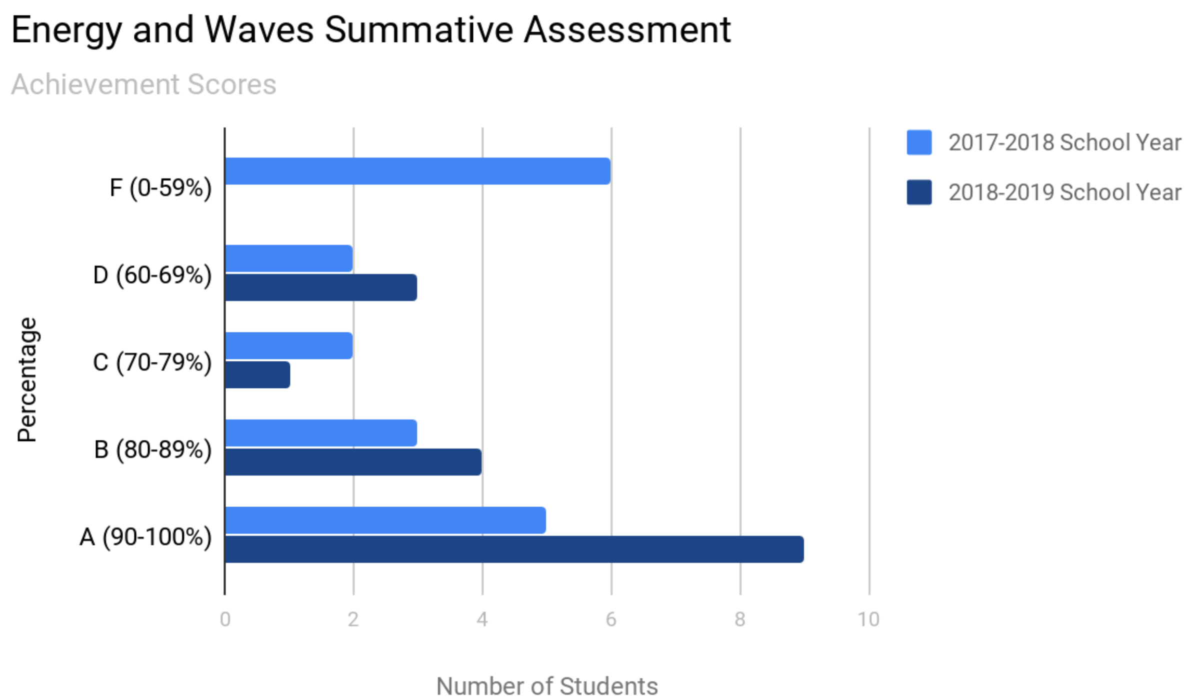


Figure 4.11. Summative test achievement scores

As shown in figure 4.11, there is a clear shift in the number of students who scored with an A (90-100%) and B (80%-89%) in the 2018-2019 school year compared to the students from the 2017-2018 school year. The total number of A's during the 2018-2018 school year was 28% compared to 50% in the 2018-2019 school year. The percent of B's in the 2018-2019 was 17% compared to 22% in the 2018-2019 school year. The number of C's in the 2017-2018 school year was 11% compared to 5% in the 2018-2019 school year. The number D's during the 2017-2018 school year was 11% compared to 17% in the 2018-2019 school year. In the 2017-2018 school year 33% of students received F's compared to no students in the 2018-2019 school year. The number of students who earned A's almost doubled. Not one student during the 2018-2019 school year received an F (0-59%) in 2018-2019. Interestingly, there is a slight increase in students who received a D (60-69%) during the 2018-2019 school year. This could be because students who worked through inquiry-based learning grasped the concept a bit better than those with less hands-on learning. It could be assumed that these students who received a D during the 2018-2019 school year might have earned an F with less of hands-on instruction as shown from students' scores in the 2017-2018 school year. Overall, there was a strong shift in academic performance from students with more student-centered instruction in the 2018-2019 school year compared to less student-centered instruction during the 2017-2018 school year. It is clear that with student-centered instruction, students were better able to grasp challenging scientific concepts.

Student Interest in Science Survey

The students in the study also completed a survey that recorded information in relation to student interest in science. During both years, the survey was given after the first science investigation completed on the unit: Energy and Waves. Each figure records what percent of each group responded to each question in a certain way. For both the 2017-2018 and 2018-2019 school year, all students participated in an anonymous survey; 32 student in 2017-2019 and 36 students in 2018-2019.

Survey question: **Of these subjects, which is your favorite in school?** There were 4 subjects students could choose from in this question: math, social studies, language arts, and science. Following this question, students had the chance to explain why they chose a certain subject. In answers where science was the clear choice, student responses were recorded and analyzed. Figures 4.12 and 4.13 indicate overall percentages of student science interest compared to other subjects during 2017-2018 and 2018-2019.

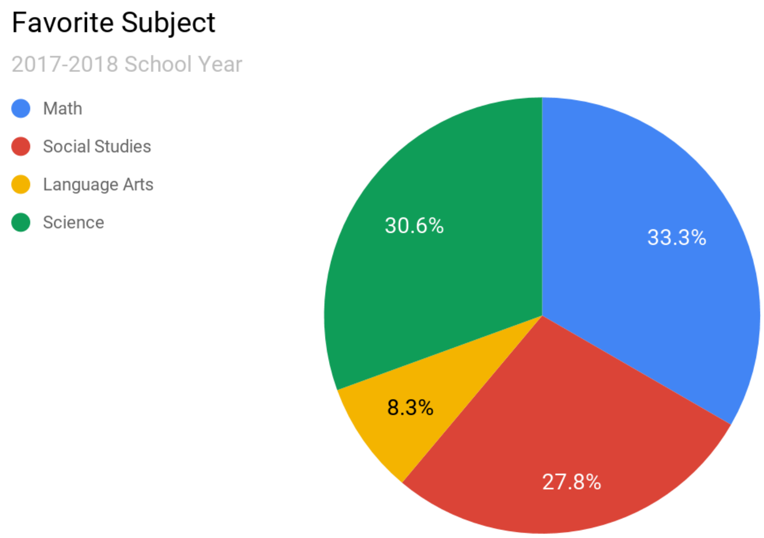


Figure 4.12. Favorite subject in school during 2017-2018 school year

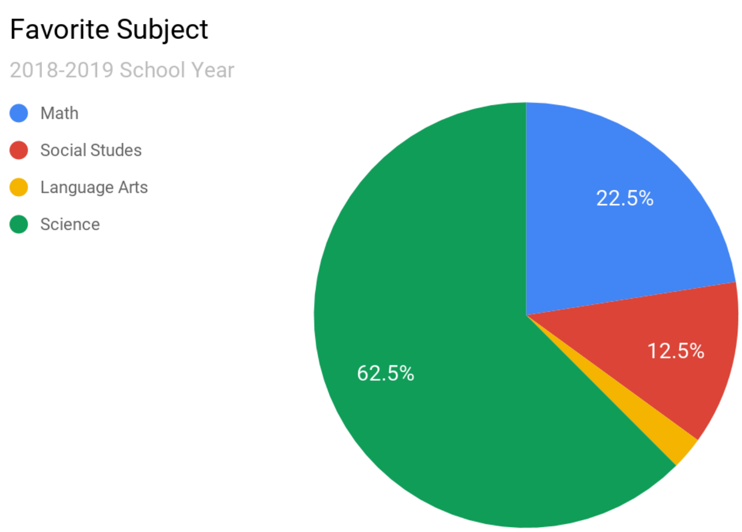


Figure 4.13. Favorite subject in school 2018-2019 school year

In the 2017-2018 school year, math was the most chosen subject at 33.3% of student responses. The second subject was science with 30.6% of students. The third subject was social studies, 27.8%, and language arts, last at 8.3 %. During the 2018-2019 however, there was a clear shift in students who chose science as their favorite subject as it received the highest percent at 62.5% of the total class responses. The second subject was math a 22.5%, social studies with 12.5%, and language arts at 2.5%.

Survey question: **Based on your previous answer, why is it your favorite subject in school?** In the 2017-2018 school year, responses pertaining specifically to science were: *"Science because you can do many experiments," "Science because I find the experiments we do very interesting," "It is interesting because I can explore electricity," "It is fun when we can experiment with things," "I like science because it is the most fun subject to do and it is a great way to learn," "I like this subject because we can do lots of experiments and have a lot of fun doing it with friends," "Science because it is the most interesting."*

In the 2018-2019 school year, responses pertaining specifically to science were: *"Because it is fun and you get to know how to do experiments," "I chose science because I like doing experiments," "I like it because we get to do fun things like playing with magnets," "It is my favorite subject because we do many experiments," "I like chemicals and explosions," "It is my favorite because I like doing experiments with my classmates," "It is my favorite subject because we can work together and it is so magnificent," "Because you use batteries, metal wires, and light bulbs to light it up," "Because it is fun to learn and it can be fun to learn and experiment is fun," Science is my favorite subject because you can create experiments and test them out," "I like science because we get to do experiments," "I like science because we get to do experiments,"* and *"I like physics and to know how things work for my secret underground lab."*

It was clear to see that during both the 2017-2018 and 2018-2019 school years, students who chose science as their favorite subject in school, liked the subject best because of the experiments that were completed from a student-centered perspective and in an inquiry-based manner.

Survey question: **Which is your favorite way to learn science?** There were 6 different options that students could have chosen in this question. The 6 choices were: reading the textbook and taking notes, filling out a worksheet related to the topic, completing an investigation related to the topic, watching a video related to the topic, reading the book then having the teacher explain it, and splitting up the lesson and explaining it to the class. Figures 4.14 and 4.15 indicate students favorite ways to learn science.

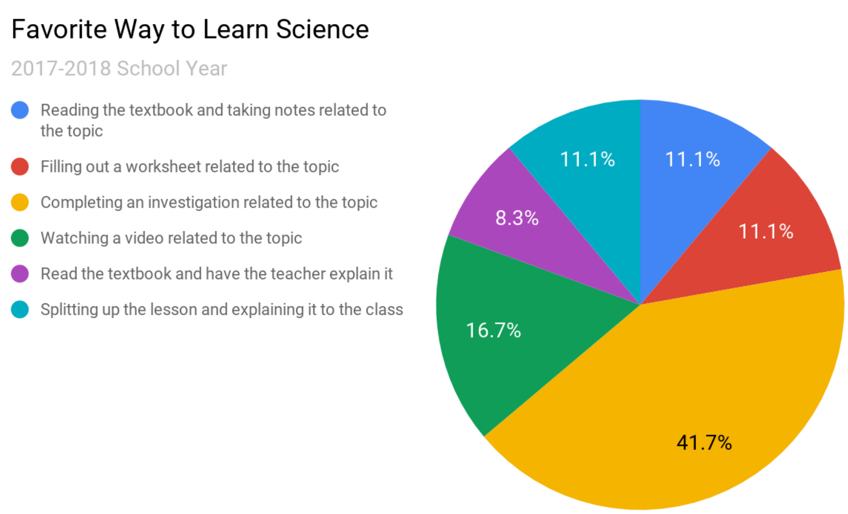


Figure 4.14. Favorite way to learn science during school 2017-2018 school year

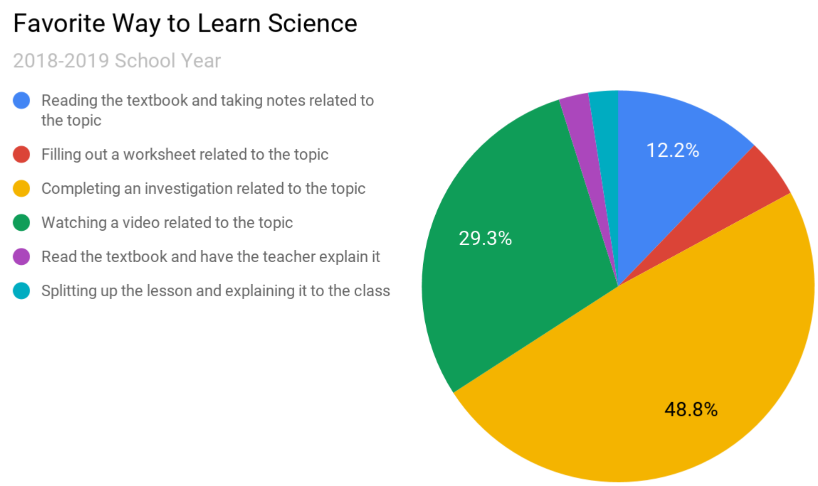


Figure 4.15. Favorite way to learn science during school 2018-2019 school year

In both 2017-2018 and 2018-2019 school years, results indicate most students enjoyed learning science best through completing an investigation related to the topic. During the 2017-2018 school year, 41.8% of students chose science investigations as their preferred way of learning science. In the 2018-2019 school year, 48.8% of students chose science investigations are their preferred way of learning science, a 7% increase from the previous school year. In both years, the second most votes were from watching a video related to the topic. During the 2017-2018 school year, 16.7% of students chose watching a video as their favorite way of learning science, compared to the 2018-2019 school year of 29.3%. Between the two years, there was a 12.6% increase in those who chose videos as their favorite way to learn science from the 2017-2018 to the 2018-2019 school year. In both years, what would be considered traditional teacher-centered styles of learning, reading the textbook, lecturing, and answering questions, were the least chosen student responses of favorite ways to learn science. During the 2018-2019 school year, it was a clear third choice, at 12.2%. In the 2017-2018 school year, reading the textbook and taking notes tied with the filling out a worksheet and "jigsawing" up the lesson. In both years, having the teacher read the textbook and explain it was the least chosen option in how the lesson should be taught.

Survey question: **How excited were you about learning science this past year?** In this next question, students chose their level of excitement towards learning science. Their responses were based on their previous science experiences, and whatever beginning experiences they had so far in fourth-grade science.

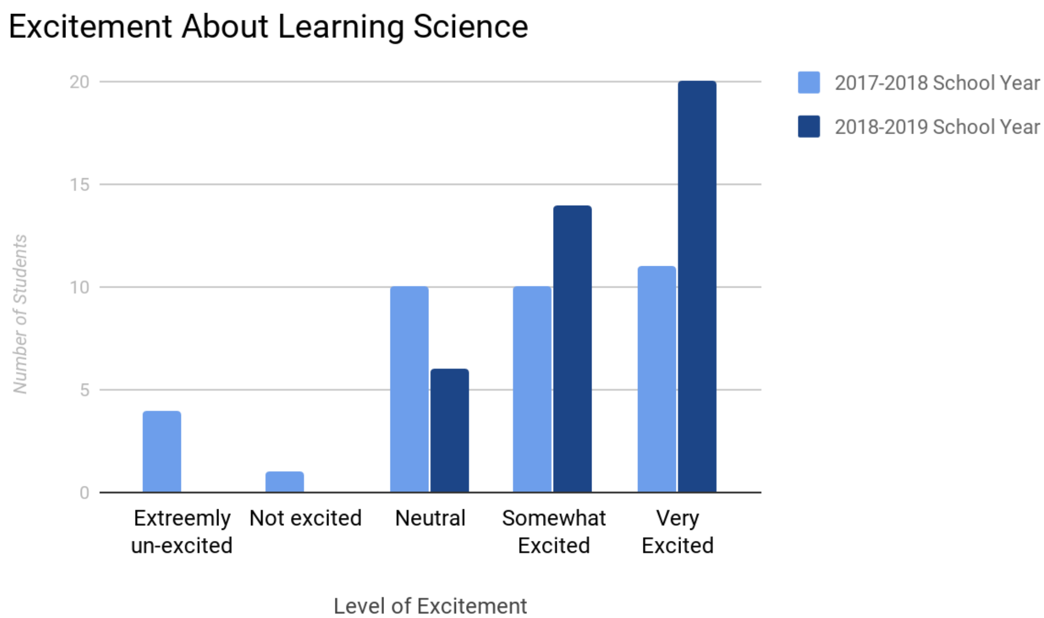


Figure 4.16. Student excitement about science during the 2017-2018 and 2018-2019 school years

During the 2018-2019 school year, there was an increase in students excitement in learning science. In the 2017-2018 school year, only 34% of students chose that they were “very excited” in learning about science this past year, while 55% of students expressed that they were “very excited” during the 2018-2019 school year. During the 2017-2018 school year, 31% of students chose that they were excited compared to 39% during the 2018-2019 school year. A shift in what received more votes during the 2017-

2018 school year is seen in the “somewhat category” as 31% of students chose this as their response during the 2017-2018 school year compared to 17% during the 2018-2019 school year. During the 2018-2019 school year, not one student chose that they were not excited or extremely un-excited about learning science the past year compared to the 2017-2018 school year where 3% of students chose that they were not excited, and 12% chose that they were extremely un-excited

Survey question: **When finished with the lesson, how interested are you in completing the answers at the end in the textbook?** For this question, students chose their level of excitement towards completing the answers at the end of the lesson after reading from the textbook. Their responses were based on their previous science experiences, and whatever beginning experiences they had so far in fourth-grade science.

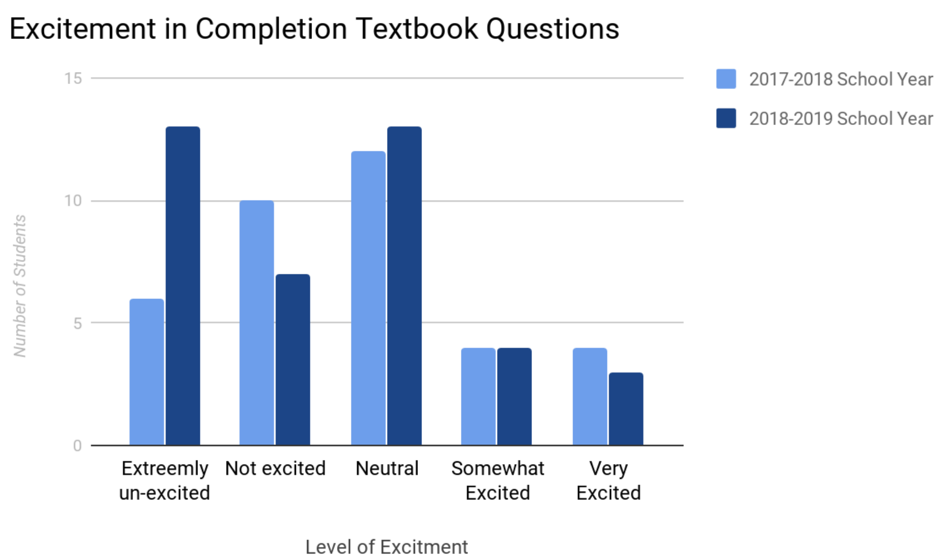


Figure 4.17. Student excitement about completing textbook questions during 2017-2018 and 2018-2019 school year

During both the 2017-2018 and 2018-2019 school years, most students were not very excited about completing the textbook questions at the end of the science lesson.

There was a clear rise in the responses between those who were neutral and those who were not excited. During the 2017-2018 school year, 37% of students were neutral in how they felt about completing the textbook questions, while 36% of students chose neutral for the 2018-2019 school year. A larger percentage of students chose that they were not excited or extremely un-excited to complete the textbook questions after the reading. During the 2017-2018 school year, 31% of students chose they were not excited compared to 19% during the 2018-2019 school year. During the 2017-2018 school year, 19% of students chose that they were extremely un-excited while in the 2018-2019 class, 36% of students shared that they were uninterested in completing the work at the end of the lesson. In both years, being somewhat excited and very excited did receive some votes but were very few compared to those who were neutral or did not care to complete the questions at the end of the lesson.

Survey question: **When trying to turn a lightbulb on, how interested were you in continuing and finishing the investigation?** During the 2017-2018 and 2018-2019 school year, both classes had the task of figuring out how to turn a light bulb on with only a few materials provided (two wires, a D-cell battery, and a small bulb). During the 2017-2018 school year, students read about how light bulbs work, and then completed an activity to light a bulb. In the 2018-2019 year, students were simply given the task of figuring out how to light the bulb, before learning about lights. They only had their own personal experiences and knowledge of light bulbs to help them. In both school years, students interest in completing the hands-on investigation was extremely high.

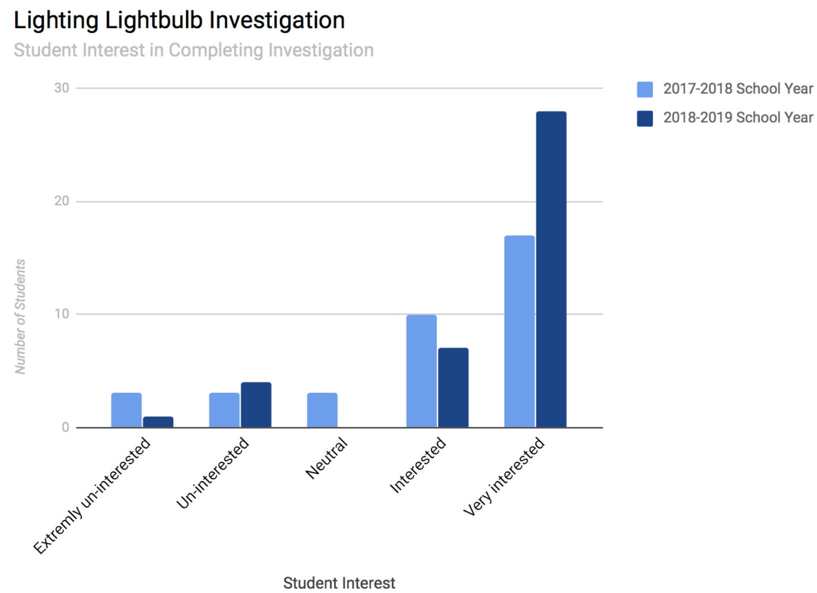


Figure 4.18. Student interest in completing the lighting lightbulb investigation

During the 2017-2018 school year, of 53% of students chose that they were very interested in completing the lighting lightbulb investigation. In the 2018-2019 school year, 78% of students chose that they were very interested in completing the hands-on activity. The second highest score was in the "interested" category with 31% of students from the 2017-2018 school year and 19% of students from the 2018-2019 school year. The students from the 2017-2018 school year showed more overall indifference or lack of interest compared to the 2018-2019 school year.

2018-2019 School Year: Student Motivation and Engagement Rubric

During the 2018-2019 school year, two rubrics were added to measure student motivation and student engagement during inquiry instruction. During the unit, the motivation and engagement rubrics were only used during one instance. The reason for this was because of the challenges that come with getting outside help in the classroom to assist in measuring this type of data. However, based on the teacher/researcher's own observations in addition to the data collected, it was assumed that overall, students were more motivated and engaged. One reason for this might be because students in the 2018-2019 school year, showed far more interest and excitement in science compared to the 2017-2018 school year. With more excitement for science, there may have been an increase in motivation to do science, and engagement with science content.

Table 4.3
2018-2019 Student Motivation Rubric Results

Motivation 2018-2019 School Year	Above and Beyond	Right There	Not There Yet
Student Investigation Interaction	9 Students	7 Students	2 Students
Data Sheets	9 Students	6 Students	3 Students
Student Science Questioning	8 Students	5 Students	5 Students

Table 4.4
2018-2019 Student Engagement Rubric Results

Engagement 2018-2019 School Year	Above and Beyond	Right There	Not There Yet
Collaboration	8 Students	7 Students	3 Students
Data Sheets	11 Students	6 Students	1 Student
Student Science Questioning	8 Students	6 Students	4 Students
Student Communication	7 Students	7 Students	4 Students

From the data represented in tables 4.3 and 4.4, it is apparent that students who participated in a student-centered science classroom had an increase in academics, motivation, and engagement. What students struggled with was student science questioning and student communication. This struggle could be due to the lack of experience participating in a student-centered classroom. Since this type of learning was a new concept for students, it is possible that with more practice, students who were not there yet, would have performed better with more experiences in student-centered instruction. Overall, class percentages demonstrated that when students did participate in student-centered instruction, achievement scores were higher both in overall notebook scores, and summative assessment scores. Additionally, students demonstrated an increase in motivation and engagement when student-centered instruction was implemented. This was shown by more active involvement during group collaboration, communication, student questioning, and completion of the data sheets during investigations. Survey results also showed that students who were more interested in learning science, had better outcomes in performance.

Chapter Summary

The purpose of this study was to examine a teacher's transition from the beginning stages of a student-centered instructional approach to a completely student-centered science classroom. The chapter provided results from the beginning stages of student-centered instruction during the 2017-2018 academic year compared to the completely student-centered classroom during the 2018-2019 academic year. The chapter first presented thematic findings and student score percentages in the student science notebooks and student summative assessments for both the 2017-2018 and 2018-2019 school years. Then, the chapter broke down each section of how the notebooks were graded and presented the results of comparative analysis conducted between school years. The same process was also carried out through students' summative assessments for both school years. Next, the chapter discussed findings from the student interest in science survey. Finally the chapter discussed the motivation and engagement rubrics that were used during the 2018-2019 school year. Results from motivation and engagement rubric analysis indicated that the more students were motivated and engaged during science investigations, the better outcome they had in both their science notebooks and summative assessments.

The results presented in this chapter indicate an increase in all three areas of student science learning (achievement, motivation, and engagement) when student-centered instruction was completely implemented in a fourth-grade classroom during the 2018-2019 academic year of the study. The principle results indicate that students were more thorough in their science notebooks and performed better on their overall notebook score. In addition, their science notebook work positively influenced students' overall score on the summative science assessment. Results also indicated that the more students were interested in science, the more they were engaged and motivated to learn the science curriculum. The next chapter of this thesis provides the "Discussion" which describes the organization of this research study. Chapter five also identifies significant implications regarding the impact of student-centered instruction within a fourth-grade science classroom as well as limitations and recommendations of this particular study.

CHAPTER V: DISCUSSION

This research study is important because it highlights some of ways that student-centered instruction in science effects student achievement, motivation, and engagement. The previous chapter of this thesis presented results of this study that sought to investigate the impact of shifting from a teacher-centered to a student-centered science instructional approach in a fourth-grade classroom. It did so by answering the following research questions:

1. What are the effects of implementing student-centered science instruction on student achievement in fourth-grade students?
2. How does the use of student science notebooks impact conceptual understanding, general interest in, and student summative assessment scores in science?
3. In what ways does implementing student-centered science instruction impact student motivation to learn science?
4. How does implementing student-centered science instruction impact student engagement in learning science?

Based on the results of this research, this chapter provides a discussion regarding the research conducted and describes how the study implications can be applied in the implementation of student-centered instruction in elementary science classrooms. Limitations of this study are then presented that indicate two areas that lack effectiveness for implementing student-centered science. The chapter then provides recommendations for research that can help answer identified issues resulting from this research. As a final point, the chapter advances concluding comments explaining why the findings of this study are important to the field of education.

Study Implications

The research reported in this study is useful to help teachers determine the effects of utilizing a student-centered instructional approach on student achievement, motivation, and engagement in a fourth-grade science classroom. Additionally, the implications of this study indicate that student-centered instruction can be a valuable way to teach science so that students acquire deep scientific conceptual understanding. Furthermore, this study indicates that hands-on science helps students learn and comprehend content in meaningful ways when compared to a more teacher-centered approach that does not afford students multiple opportunities to interact with science in similar ways as actual scientists and engineers do.

The implications from this research indicate that there needs to be a clear shift from teacher-centered to student-centered instruction if teachers are to be able to properly teach science using the NGSS. A number of research studies examined in this thesis revealed support for the shift from the "traditional" style of teaching, to a student-centered hands-on approach. For example, Minner, Levy, and Century (2010), concluded in an eighteen-year study that students who were taught science with an inquiry-based approach to learning exhibited higher amounts of "inquiry saturation." Students took more responsibility in their learning, which improved their science conceptual learning (Minner, Levy, & Century, 2010). Research findings also indicate that with student-centered instruction, students are more likely to understand the natural world if they are interacting directly with natural phenomena by using instruments as well as their senses to make sense of the world around them (National Science Board, 1991). Further implications of this study validate these research findings by evincing that rather than having to memorize large quantities of information, by engaging students in activities that stimulate interest in science content, students acquire knowledge and practical problem solving skills needed for the real world. This study indicates that the success of student-centered instruction depends on whether teachers are creating optimum classroom environments for hands-on, minds-on learning.

Student-Centered Science Instruction and Student Achievement

Based on student academic achievement scores in science notebooks and summative tests, results of this study indicate that there is a positive relationship between student-centered instruction and academic achievement. In survey responses, the clear choice in the way students responded that they wanted to learn science was with less traditional methods of instruction (lecture, note taking, responding to questions at the end of a lesson or unit teacher guiding the instruction, and so forth). The majority of survey responses indicated that learning through inquiry and hands-on instruction were what students desired most in the science classroom. This study showed that when the teacher/researcher utilized student-centered science instruction, students were more likely to respond positively to instruction since students became more invested in their own science learning.

The findings from this study found that students who were more engaged and motivated, were more involved in the learning process, and performed better overall. With more experience in teaching with a completely student-centered approach to instruction, the teacher/researcher created a classroom environment where students were able to thrive academically. The implications of this study suggest that in order for students to be engaged and motivated when learning science, teachers must provide students with the proper scaffolding as well as establish clear classroom expectations of how to interact with science content during inquiry-based activities, lessons, and units. Teachers cannot just jump into teaching with a student-centered style of instruction. Necessary training, preparation, and practice are key elements to successfully implement this approach of teaching science.

Teachers need to embrace the power of student-centered instruction and its benefits for student success in the science classroom. Now more than ever, students must be prepared to enter a technology driven workforce. Jobs require young professionals to critically think and problem solve—skills which are developed through student-centered instruction. Traditional teacher-centered instruction does not provide students with the skills needed to be successful in the 21st century workforce. Additionally, states which have adopted the NGSS have already switched their statewide testing to reflect this shift in how science should be taught. Science tests are no longer multiple choice, or true or false questions. Science tests include performance tasks where students must read a scientific scenario, then must problem solve, graph, and critically respond to what is being explained in a thorough manner. Without proper practice in how to interact with science content in this manner, students will not be successful on statewide exams.

Scientific Conceptual Understanding and Student Science Notebooks

It is evident from this research study that student learning does not just happen through hands-on experiences, it also requires minds-on participation in learning science. In order to measure student's grasp on a science topic, there must be some form of written work to go along with the investigation. An important finding that resulted from this study is that students who were more thorough in completing their notebook work scored better—not only on their overall notebook score—they also scored better on the summative assessment. What this indicates is that students who are able to articulate their findings and make use of newly acquired scientific terminology during an investigation tend to improve in their overall science learning. This is because these students have grasped the concept better during the hands-on inquiry. By checking over student's notebooks throughout the unit, teachers can identify areas of need and provide additional support in the development of student understanding regarding new scientific concepts being learned.

Science Notebooks and Student Interest in Science

Another important finding related to student science notebooks in this study was that the more students were interested in science, the better they performed in their science notebooks. When students were more engaged and motivated to finish the investigation, students work and explanations for "what did not work" and "what did work" were more thorough. Student drawings were more detailed and their overall responses were more complete with clear explanations based on their own experiences during the investigations. When students were more interested in their own learning, they were more invested and responded more thoroughly about their own findings. The use of science notebooks can and does provide teachers with an excellent pedagogical tool that increases student interest in science. Science notebooks can increase student interest by providing them with a place to work through their understanding of scientific concepts in their writing and drawing. Thus, increasing their potential to learn the content in more meaningful ways.

Student Science Notebooks Impact on Summative Assessment Scores

Another interesting finding that resulted from this research was that there was a clear relationship during both academic years of the study (2017-2018 and 2018-2019) between students notebook scores and summative assessment scores. In other words, students who performed well on their notebooks, performed well on their summative assessment compared to those who did not. Students who were already thorough in their responses in their notebooks, were thorough on their short answer test questions. Those who correctly used scientific terminology in their notebooks, scored higher on the vocabulary section of the summative assessment. Study implications point to the fact that implementing the use of science notebooks produces an overall benefit on summative science assessments when students take charge of their own learning experience. Moreover, students who thoroughly completed clearly articulated science investigations using their science notebooks scored higher in all areas of the summative assessment compared to students who did not.

The Impact of Student-Centered Science Instruction on Motivation and Engagement

The impact of students' motivation was measured through students thoroughness of their notebooks as well as student motivation rubrics during hands-on instruction. When students were motivated during investigations, they were more likely to be thorough in their work when completing data sheets and describing what happened during the lab. When students displayed motivation during science instruction they acquired higher achievement scores in their lab notebooks as well as on their summative assessment scores.

Student engagement was measured in; (a) the way students collaborated, (b) how they completed their data sheets, (c) science questioning, and (d) their communication of ideas. Students in a completely student-centered classroom exhibited more involvement and engagement during hands-on instruction. Students who exhibited above average engagement in all four areas performed better in all areas of the unit study. Students who were highly engaged in their own science learning, wanted to share and show their ideas with each other and the teacher/researcher. Highly engaged students also productively problem solved through questioning and collaborated well with their peers. Additionally, student engagement was measured through student interest in science surveys across both school years. When students were engaged, they wanted to learn and comprehend scientific phenomena. As a result, students clearly wanted to use their own experiences of both failure and success to make sense of their own learning. What this indicated was that when students were more engaged with the work they had positive outcomes in their own science learning.

Study Limitations

Two areas of this study are presented as essential limiting factors to consider when implementing student-centered instruction in a science classroom. To capitalize on the academic advantages of student-centered instruction, teachers need to be comfortable with various issues that may arise when implementing student-centered instruction.

General Student-Centered Instruction and Class Comparison Limitations

The first identified study limitation has to do with class comparison that was conducted in this study. In this research study, two different classes were used when examining a more traditional teacher-centered approach to instruction versus a class with a completely student-centered instructional approach. During the 2017-2018 school year, implementing the NGSS was in its first year. In the 2018-2019 school year, students were in their second year of NGSS implementation. In addition, each student and each overall class had different strengths and weaknesses, it is possible that the second year students had some previous experience with a more student-centered science classroom. Further research should be conducted with two different classrooms in the same grade-level, at the same school, and during the same academic year. This would allow a more accurate account of what students already know and have experienced before being tested. Additionally, students should come with the same level of abilities (e.g. the same number of gifted students, EL students, special ed. students).

Adequate NGSS Preparation as a Limitation in Science Instruction

Teachers must have ample NGSS training and clear knowledge of their grade-level standards in order to skillfully shift to a student-centered teaching approach. If teachers are not adequately trained in the NGSS and are not trained to implement a student-centered classroom, it is likely that students would not be as successful in mastering the content. If teachers are not familiar with implementing a student-centered classroom, students will not have the proper scaffolding and guidance needed to be successful in their learning. Additionally, teachers must be well read in the NGSS and have a deep understanding of the standards for their grade-level. Teachers need to have a strong foundation and grasp of the scientific concepts students should know to facilitate student learning. Training on the NGSS is required for teachers to fully interpret the standards and learn how to skillfully implement student-centered instruction in the classroom. Without proper training, students may have fun doing science but may not acquire the necessary skills and comprehension needed to adequately complete the investigation.

Additionally, teachers must plan and order supplies with ample time before they are needed for the investigations. If teachers do not have the required materials and time needed to prepare for proper inquiry learning, students will not be able to participate in an inquiry-based student-centered science classroom. At each grade-level, different materials are required as different concepts are being taught according to the NGSS. Not only should teachers plan and prepare for the lessons to be covered, teachers must also make sure they have adequate supplies far in advance before implementing a particular NGSS lesson or unit of instruction. Teachers cannot only rely on textbooks anymore, they need to allow time for gathering supplies, sharing supplies with other teachers, and even shipping. Because special supplies are needed to carry out student-centered instruction, adequate funding is required to be able to supply a student-centered science classroom. Without sufficient supplies, teachers are left to teach with traditional methods of instruction because of the lack of the necessary materials.

Finally, teachers need to have a prepared notebook for students to organize their work from each investigation. If teacher's do not supply the necessary means for students to access learning through student-centered instruction, it is evident that students will not be successful. Teachers must plan out subsequent lessons to make sure that every week, students are using the previous week's instruction to help develop their learning during the coming week. Students need hands-on activities and lessons that build upon one another rather than random activities all related to the standard. Deep conceptual understanding occurs when students can use their experiences to form ideas and make sense of the scientific concepts. To go about preparing science notebooks, teachers must use the NGSS as a guide to see where students need to be, and backwards plan what they will need to know, in order to master the standard. Depending on each grade-level, teachers must create a place for students to record, draw, and analyze their data in an organized sequential manner.

Study Recommendations

The purpose of this research study was to investigate the impact of transitioning from a less student-centered instructional approach to teaching science in a completely student-centered science classroom. The teacher/researcher in this study taught fourth-grade science and transitioned from teacher-centered to student-centered science teaching over the course of three years. However, the data for this study was collected during her second and third years of teaching when she more formally implemented a student-centered science curricular approach. Moreover, during her third year of teaching fourth-grade science, the teacher/researcher completely immersed her students in a student-centered science teaching. The following specific recommendations are presented from this thesis.

Student-Centered Instruction at All Grade-Levels

First, a recommendation for future studies would be to look at student-centered instruction and how it impacts student achievement, motivation, and engagement at all K-12 grade levels. In this study, it was discovered that student-centered instruction positively impacted student achievement, motivation, and engagement in a fourth-grade classroom. However, the impact of examining student-centered science instruction at all grade-levels was not explored. Therefore, further studies should examine this issue more closely in order to better understand if student-centered instruction is the best approach to teaching science at all grade levels. For example what would student-centered instruction look like in lower grade-levels? These teachers may need additional adult support to make sure that students are getting the necessary scaffolds to learn through inquiry-based instruction. Additionally, looking at statewide science test scores at fifth grade, seventh grade, and ninth grade should be conducted to see if there is an improvement in achievement scores when teachers transition to a student-centered instructional approach. Because the NGSS are so new, a longitudinal study should be carried out to see how student achievement scores may change over time and across grade levels with a student-centered approach to learning.

Examining Student Interest in Science Related to Achievement in Science

Students in the 2018-2019 school year exhibited higher interests overall in science compared to the students of the 2017-2018 school year. This was found during their student interest in science survey responses. Looking solely at students' interest in science and its impact on achievement scores is another recommendation that should be explored in future studies. Future studies might be able to take the information gathered to further understand if there is a relationship between students' interest in science and whether or not there is a clear connection to their academic achievement.

Additionally, administering a student interest in science survey once at the beginning of the unit and once at the end of the unit could be carried out to see if there is a positive relationship between student-centered instruction and student interest in science. It is anticipated that after students complete science in a student-centered classroom, students will be more interested in learning science. If there is a positive correlation between student-centered instruction and students' desire to learn science, it is expected that students would perform better in future science subject areas and display higher achievement scores.

The Need for NGSS Professional Development (PD) and Student-Centered Instruction

Finally, it is evident, that without the necessary professional development training, teachers cannot successfully implement a student-centered science classroom. In order to successfully run a student-centered science classroom, teachers must participate in PDs geared towards understanding the NGSS, what inquiry-based learning looks like in the classroom, and how to facilitate learning in a student-centered classroom. Teacher's cannot just change how they teach science overnight, it is a process in which they need proper training and support to implement in their own classroom.

Conclusion

This study illuminates one of the central the goals for the Next Generation Science Standards (NGSS) to shift the way students are taught science to be more in alignment with the ways that actual practicing scientists and engineers do science. The NGSS requires teachers to shift their old teacher-centered (e.g., lecturing and having students read textbooks and respond to questions within the text) teaching practices to a more student-centered approach that gets students participating in science in more meaningful ways. The results of this study clearly indicate that there was a difference in the levels of student's academic achievement, motivation, and engagement when taught from a completely student-centered instructional approach. In this study, student-centered instruction was used to teach a fourth-grade unit on energy and waves—both in the NGSS for fourth-grade. Moreover, implementing a completely student-centered teaching perspective was used to measure whether it had a positive impact on student academic achievement, motivation, and engagement towards science curricula. Overall, students who had more hands-on inquiry activities were more motivated to complete the work and assignments compared to students who were taught from a more teacher-centered perspective. The results of this research study can inform teachers about why shifting to student-centered instruction is the best way to teach students to participate in science with the NGSS. Finally, the findings of this research have significance for improving students' academic achievement, motivation, and engagement in science when teachers shift to a student-centered instructional approach.

References

Achieve, Inc. (2013). Next Generation Science Standards. Retrieved from http://www.nextgenscience.org/

Akinoglu, O., & Tandogan, R. O. (2007). The Effects of Problem-Based Active Learning in Science Education on Students' Academic Achievement, Attitude and Concept Learning. *Online Submission*, *3*(1), 71-81.

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry- based approach known as the Science Writing Heuristic to traditional science teaching practices: Are there differences?. *International Journal of Science Education*, *29*(14), 1745-1765.

Barton, K. C., & Levstik, L. S. (2004). *Teaching history for the common good*. Routledge.

Bruce, B., & Levin, J. (2001). Roles for new technologies in language arts: inquiry, communication, construction, and expression. In J. Jenson, J. Flood, D. Lapp, & J. Squire (Eds.), The handbook for research on teaching the language arts. NY: Macmillan.

Bull, G., & Bell, R. L. (2008). Educational technology in the science classroom. *Technology in the secondary science classroom. NSTA Press, Arlington*, 1-7.

Bybee, R. W. (2013). Next generation science standards: For states, by states. Washington, D.C.: National Academies Press

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, CO: BSCS*, *5*, 88-98.

"California Science Standards Information on the next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve." *California Department of Education*, 19 June 2018, www.cde.ca.gov/pd/ca/sc/ngssintrod.asp.

Cakir, M. (2008). Constructivist approaches to learning in science and their implication for science pedagogy: A literature review. International Journal of Environmental and Science Education, 3(4), 193– 206.

Churches, A. (2008). Bloom's taxonomy blooms digitally. *Tech & Learning*, *1*, 1-6.

Condliffe, B., Quint, J., Visher, M.G., Bangser, M. R., Drohojowska, S., Saco, L., & Nelson, E. (2017). Project-based learning: A literature review. Working Paper. *MDRC*.

Data Access and Dissemination Systems (DADS). (2010, October 05). American FactFinder - Community Facts. Retrieved from https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk

Dewey, J. (1910). Science as subject-matter and as method. *Science*, 121-127.

Driscoll, M.P., Moallem, M., Dick, W., & Kirby, E. (1994). How does the textbook contribute to learning in a middle school class? Contemporary Educational Psychology, 19, 79–100.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109.

Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional science*, *25*(3), 167-202.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*(3), 223-252.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational psychologist*, *42*(2), 99-107.

Marrero, M. E., Gunning, A. M., & Germain-Williams, T. (2014). What is STEM Education?. *Global Education Review*, *1*(4).

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1997). Enacting project-based science. *The elementary school journal*, 341-358.

Mazur, A. D., Brown, B., & Jacobsen, M. (2015). Learning designs using flipped classroom instruction conception d'apprentissage à l'aide de l'instruction en classe inversée. *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, *41*(2).

McCall, A. (2006). Supporting exemplary social studies teaching in elementary schools. *The Social Studies*, *97*(4), 161-167.

McComas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In *The nature of science in science education*(pp. 41-52). Springer Netherlands.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry- based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of research in science teaching*, *47*(4), 474-496.

National Center for Educational Statistics. (1999). *What happens in classrooms? Instructional practices in elementary and secondary schools 1994–95 (NCES 1999–348)*.

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Academies Press.

National Science Board. (1991). Science & engineering indicators-1991. Washington, DC: U.S. Government Printing Office. (NSB 91-1)

Ong, F., & Bruton, S. (2000). *Science content standards for California public schools: Kindergarten through grade twelve*. Sacramento, CA: Dept. of Education.

Overby, K. (2011). Student-centered learning. *ESSAI*, *9*(1), 32.

Passmore, C.M., & Svoboda, J. (2012). Exploring opportunities for argumentation in modelling classrooms. *International Journal of Science Education, 34*(10), 1535-1554

Pedersen, S., & Liu, M. (2003). Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development*, *51*(2), 57-76.

Quinn, H., Lee, O., & Valdés, G. (2012). Language demands and opportunities in relation to Next Generation Science Standards for English language learners: What teachers need to know. *Commissioned Papers on Language and Literacy Issues in the Common Core State Standards and Next Generation Science Standards*, *94*, 32.

Reiser, B. J. (2013, September). What professional development strategies are needed for successful implementation of the Next Generation Science Standards. In *Paper written for the Invitational Research Symposium on Science Assessment* (Vol. 24, p. 25).

Rosenfeld, S., & Ben-Hur, Y. (2001). Project-Based Learning (PBL) in Science and Technology: A Case Study of Professional Development.

Saye, J. W., & Brush, T. (2004). Scaffolding problem-based teaching in a traditional social studies classroom. *Theory & Research in Social Education*, *32*(3), 349-378.

Schneider, R. M., Krajcik, J., Marx, R. W., & Soloway, E. (2002). Performance of students in project- based science classrooms on a national measure of science achievement. *Journal of Research in Science Teaching*, *39*(5), 410-422.

Schwerdt, G., & Wuppermann, A. C. (2011). Is traditional teaching really all that bad? A within-student between-subject approach. *Economics of Education Review*, *30*(2), 365-379.

Simon, H. A. (1973). The structure of ill structured problems. *Artificial intelligence*, *4*(3-4), 181-201.

Songer, N. B., Lee, H. S., & Kam, R. (2002). Technology- rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy?. *Journal of Research in Science Teaching*, *39*(2), 128-150.

Spiro, R., Feltovich, P., Jacobson, M. & Coulson, R. (1991). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. *Educational Technology* 5: 24–33.

Yilmaz, K. (2008). Constructivism: Its theoretical underpinnings, variations, and implications for classroom instruction. *Educational Horizons*, *86*(3), 161-172.

Zakaria, E., & Iksan, Z. (2007). Promoting Cooperative Learning in Science and Mathematics Education: A Malaysian Perspective. *Online Submission*, *3*(1), 35-39.

Appendix A

Student Interest in Science Survey

Student Interest Survey

Students of Room 21

1. **Are you a girl or boy?**
   Mark only one oval.
   - ( ) Girl
   - ( ) Boy
   - ( ) Other: ____________________

2. **Of these subjects, which is your favorite in school?**
   Mark only one oval.
   - ( ) Math
   - ( ) Language Arts
   - ( ) Science
   - ( ) Social Studies

3. **Based on the previous answer, why is that subject your favorite in school?**

   ____
   ____
   ____
   ____
   ____

4. **What is your favorite way to learn science?**
   Mark only one oval.
   - ( ) Reading the textbook and taking notes
   - ( ) Completing an investigation related to the concept we are learning
   - ( ) Splitting up each lesson of a chapter and teaching it to the class
   - ( ) Filling out a worksheet related to the the concept we are learning
   - ( ) Watching a video related to the concept we are learning
   - ( ) Other: ____________________

5. **How excited were you about learning science this past year?**

Mark only one oval.

	1	2	3	4	5	
ugh...	⬭	⬭	⬭	⬭	⬭	YAY!

6. **When finished with a lesson in science, how interested are you in completing the worksheet questions at the end of the lesson?**

Mark only one oval.

	1	2	3	4	5	
Not very excited, I'd rather be doing something else related to the lesson	⬭	⬭	⬭	⬭	⬭	Very excited! It is fun working on it!

7. **When trying to turn a lightbulb on, how interested were you in continuing and finishing the investigation?**

Mark only one oval.

	1	2	3	4	5	
Not very excited, I'd rather be doing something else related to science.	⬭	⬭	⬭	⬭	⬭	Very excited! It was fun working on it!

8. **In a short answer, please share any other information related to your experience with learning science.**

Appendix B

Energy and Waves Summative Assessment

Name: ______________________________ #: _______ Date: _____________

Energy and Waves

Directions: Write the letter of the vocabulary word next to the definition that matches.

A. Amplitude	**E.** Frequency	**I.** Parallel circuit
B. Closed circuit	**F.** Insulator	**J.** Refraction
C. Conductor	**G.** Opaque	**K.** Series circuit
D. Cochlea	**H.** Open circuit	**L.** Wave length

1. _____ A circuit that is complete.
2. _____ A circuit that is not complete.
3. _____ Electricity can pass through this type of object
4. _____ Very large resistance to the flow of an electric current
5. _____ A closed circuit connected along a single path so the same current flows through all the components.
6. _____ A closed circuit in which the current divides into two or more paths side by side.
7. _____ The distance from the center line in a wave to the top of the curve.
8. _____ The number of waves passing a point in a certain time.
9. _____ The distance from any point on one wave to the same point on the next wave.
10. _____ Materials that do not let any light shine through
11. _____ The part of the ear that has many tiny hairs that vibrate when sound reaches it
12. _____ Light bending when it moves through different substances like water.

Multiple Choice

13. Aluminum foil is an example of a(n) _____.

    a. Insulator
    b. Magnet
    c. Battery
    d. Conductor

14. The lights in your house are an example of a _____.

    a. Short circuit
    b. Series circuit
    c. Parallel circuit
    d. Circular circuit

15. Sound is caused by ______________ that make waves.

    a. Light
    b. Vibrations
    c. Frequency
    d. Reflection

16. The bigger the ________________ the louder the sound.

    a. Amplitude
    b. Refraction
    c. Transparency
    d. Straw

17. In addition to hearing, ears are responsible for ________________.

    a. Balance
    b. Energy
    c. Light
    d. Waves

18. ________________ in the form of sound waves enter the ear canal and then travel down the canal and run into the eardrum.

    a. Signals
    b. Balance
    c. Fluid
    d. Energy

Short Answer

19. What causes magnets to attract to each other? What causes magnets to repel from each other?

____
____
____
____

20. What happens when you disconnect a bulb from a series circuit? Explain.

____
____
____
____

21. Which part of the eye communicates with the brain? What does your brain do with these messages?

____
____
____
____

22. In the space below, draw a wave with a high frequency.