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An Investigation of the Effects of Integrating Science and Engineering Content and Pedagogy in an Elementary School Classroom

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A thesis submitted to the faculty of
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Master of Arts

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ABSTRACT

An Investigation of the Effects of Integrating Science and Engineering Content and Pedagogy in an Elementary School Classroom

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Master of Arts

Fewer students in the United States are choosing to study and enter careers in the STEM disciplines—Science, Technology, Engineering, and Mathematics. This problem is being addressed through current educational reforms focusing on Integrated STEM curriculum and instructional design. This mixed-method quasi-experimental study researched the effects of science-engineering integration on student learning, student attitudes, and student interests in science within an elementary setting through the creation and implementation of an integrated science and engineering unit of instruction focused on the water cycle. Comparisons of student performance on end-of-unit science assessments revealed no significant differences in student learning between students who experienced an integrated unit of instruction and those who received an un-integrated science unit. However, increased student learning and interest in science was evidenced in responses to a student survey. Inasmuch as there is little in the way of frameworks to guide the legitimate integration of science and engineering instruction, this study offers a guide for teachers along with evidence of its efficacy.

Keywords: STEM integration, Student Learning, Student Attitudes and Interests

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Chapter 1

Introduction

Across the United States political leaders, educators, and businessmen are issuing an urgent call for reform in STEM education (*Rising above*, 2005; Hess, Kelly, & Meeks, 2011; National Research Council, 2011; Obama, 2011). The term “STEM,” an acronym for Science, Technology, Engineering, and Mathematics, is credited to Judith A. Ramaley, former assistant director of the National Science Foundation (Doheny, 2011). Calls for reforming STEM education have coincided with an increased use of the term “STEM” in a variety of educational contexts.

These calls for STEM reform have occurred in response to recent reports which claim that the level of student achievement of United States students in STEM-related subjects is below that of other major international competitors (OECD, 2010; TIMSS, 2011). The Committee on Science of National Academies reported that the American public holds deep concerns about public education and the performance of their students and is particularly dissatisfied with student performance in the STEM disciplines (*Rising above*, 2005). The National Research Council has called for politicians to hold the science, technology and engineering disciplines of STEM education to the same level of importance as mathematics and literacy education (2011). The current president of the United States, Barack Obama, spoke of STEM issues during his state of the union address calling for parents, homes, and communities to join teachers in improving STEM education (Obama, 2011). The National Governors Association (2007) has called upon educators at all levels to improve STEM curriculum through designing instruction that includes all STEM disciplines, finding and implementing best instructional practices in STEM education, and increasing expectations for student learning within these disciplines.

Educators and politicians are even extending the call to the business world, as the U.S. Chamber of Commerce made a direct plea to industries and companies for assistance in stepping forward to the challenge of influencing STEM education, seeing as they are future employers who understand the rigor needed in workforce preparation that occurs through education (Hess, Kelly, & Meeks, 2011; Poe, 2011).

What prompted this urgent call for various kinds of reform in STEM education from such a variety of people? Concerns come from multiple reports describing declining interest in STEM education and declining numbers of people employed in STEM-related fields or STEM research. The Committee on Prospering in the Global Economy of the 21st Century reports that the number of U. S. students choosing to study science, technology, engineering, and mathematics is declining (2007). The National Science Board has reported information from surveys from the last two decades revealing that one third of freshman at universities across the nation planned to study science and engineering, but recently this number has dropped (2010). Along with the decline in interest in STEM, data also confirm that currently fewer people are involved in careers within the STEM disciplines. This decrease in numbers is not due to lack of employment opportunities as natural progress in knowledge and technological advancements of the 21st century had led to a dramatic increase in the number of jobs available within science and engineering since 1950, but more than 60 percent of those jobs require bachelor’s and master’s degrees while less people are being prepared to fill those positions (National Science Board, 2010). Along with a decreasing number of people able to fill employment opportunities, research within STEM disciplines is decreasing significantly due to lack of funding (CPGE, 2007).

In the face of declining numbers and new challenges of the present, those involved in careers within STEM disciplines are still finding ways to continue to make major advancements and contributions to society. One of the ways that progress within STEM disciplines continues to go forth is through the use of collaboration and integration. The Massachusetts Institute of Technology issued a report citing major advancements in STEM and crediting their success to a special kind of collaboration and integration called convergence. Convergence is defined as "the merging of technologies, processing disciplines, or devices into a unified whole that creates a host of new pathways and opportunities" (Sharp, 2011, p. 4). Convergence combines processes for research or new methods of design, applies them in new ways, and facilitates the creation of new products, making the idea much more powerful than just simply integrating subjects or disciplines—"Convergence is the result of true intellectual cross-pollination" (Sharp, 2011, p. 9). The report further explains that the goals of convergence include providing a new knowledge base as well as enabling innovation, and in consequence claims convergence to be a process for providing the stability of the future. This claim is supported by multiple examples of success in the medical and bioengineering fields, where the collaboration of highly specialized individuals yielded new life changing discoveries and technologies such as nanotechnology for chemotherapy and imaging technology to prevent blindness (Sharp, 2011).

Other institutions are becoming involved in promoting convergence. The National Science Foundation (NSF) prepared a report summarizing research and education projects that demonstrate the nature of convergence or meet the goal of convergence by finding ways to naturally bring diverse fields together. Many of these projects are being funded by grants from the NSF in order to promote and encourage multidisciplinary research and education (Bainbridge, 2004). Another source for encouraging convergence has been the University of

California at Berkeley, through their competition called *Big Ideas@Berkeley*. This competition caters to students to form interdisciplinary teams to seek answers and possible solutions to some of the world's current questions and problems like purifying water or diagnosing malaria (Berrett, 2011).

Statement of Problem

While experts in the STEM fields are looking to convergence as the method for making advancements in our society, the problem of preparing students who have the knowledge and skills needed to join and collaborate in STEM fields still remains. STEM curriculum integration within education may be the key to answering this problem because early attempts at integrative STEM education seems to be resulting in a greater number of students choosing STEM careers than conventional methods within STEM education (Gallant, 2011; Laboy-Rush, 2011; Sanders, 2009). Integration of curriculum within STEM disciplines is being researched at multiple levels within education. At the university level curriculum is being designed for preservice and inservice teachers to assist them in developing STEM-related knowledge and teaching skills (Carr & Strobel, 2011; Chin, Duggan, & Kamarthi, 2011; Cunningham, Lachapelle, & Keenan, 2010). Other studies present arguments for integrating STEM based on support from the psychological perspective (Newcombe et al., 2009; Sanders, 2009; Wai, Lubinski, & Benbow, 2009). Literature in educational research contains some examples of STEM integration within K-12 education, but more studies within elementary level are needed (Cantrell, Pekcan, & Itani, 2006; Cunningham, Lachapelle, & Hertel, 2012; Penner, Lehrer, & Schauble, 1998; Satchwell & Loepp, 2002; Wendell & Lee, 2010). Additionally, of these studies many lack specific detail on what integrated instructional and curricular design looks like.

Statement of Purpose and Research Questions

The purpose of this study is to integrate science and engineering content and pedagogy using a detailed instructional design plan within an elementary classroom and investigate the effects of the integration on student learning. This study seeks to investigate how an integrated science and engineering unit may effect student learning and student attitudes and interest. Therefore, the study seeks to answer these questions:

1. What effect does integrated science and engineering content and pedagogy have on student performance and student attitude and interest in science?
2. How does that student performance vary across measures that differ as to cognitive level?

Limitations

Limitations to this study should be addressed. First, the participants of the study were students in pre-existing classes and thus previously determined as the control and treatment groups, meaning there may be unknown confounding variables since the participants in the study were not randomly assigned. Proper statistical analysis procedures were used to check for significant differences between these two non-random groups. Second, there may have been a difference in the teaching strategies of implementing and delivering lesson plans between the two teachers of the groups being compared. However, like the previous limitation addressed, proper statistical analysis procedures were used to discover any teacher effect. Third, the sample size of the participants was small and the time period of instruction was brief. Results may not be generalizable to other situations. Finally, limitations exist due to the fact that the teacher of the treatment group is also the researcher for this study. To avoid the bias inherent in this limitation, both the control group teacher and treatment teacher planned lessons and instructional activities together as well as developed the pre and post-assessment. A test blueprint was used in the development of these assessments to ensure the validity and reliability.

Chapter 2

Review of Literature

Recent calls for educational reform encourage improvement in STEM education, resulting in some research that examines the effects of integrating the STEM disciplines within education. This research study suggests that educators who use the pedagogy of integration may be able to meet student needs and help students achieve greater levels of learning (Cunningham, Lachapelle, & Hertel, 2012; Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman, 2005; Kolodner et al., 2003; Sadler, Coyle, & Schwartz, 2000; Satchwell & Loepp, 2002).

The literature review for this study, grounded in the current literature on STEM education, will present a history of reform within STEM education, a general overview of integration—including key factors needed to improve STEM education through integration, and current research exploring integration within STEM education.

History of Reform within STEM Education

The current call for STEM reform results from a history of educational reform that has occurred in the United States over the last sixty years. This section will introduce the major reform movements and articulate how those movements have influenced current STEM reform initiatives.

The Soviet Union's successful launch of Sputnik in 1957 triggered an urgent call for educational reform from political leaders of the United States, which was still recovering socially and economically from the effects of World War II. Political leaders believed that in order to ensure the future and safety of our country and to aid in recovering from the loss of talent caused by deaths in World War II more scientists and mathematicians were needed. This need led to several educational reform movements.

For example, concerns about science instruction led to the Curriculum Reform Movement (DeBoer, 1991) of the 1950s and 60s. During this movement many courses were developed to orient students, particularly those who were judged to possess a high science aptitude, toward~~s~~ careers within mathematics and science (Hurd, 1998). Science curricula and textbooks were rewritten according to the nature of inquiry within the various scientific disciplines. Disciplinary studies within science (e.g., physics, biology, chemistry) were designed by curriculum makers to increase rigor and encourage students to understand the nature of scientific research, ultimately presenting science to students in a way that encouraged them to think and act like scientists (DeBoer, 1991; Shamos, 1996). Reformers hoped their efforts would generate scientists who would aid the country in sustaining itself as a global leader (DeBoer, 1991; Gallant, 2011).

Similar efforts characterized mathematics education reform during this same time period. Many groups, including the American Mathematical Society, the National Council of Teachers of Mathematics, and the Committee on School Mathematics at the University of Illinois, led by Max Beberman, worked to develop new curricula for high school mathematics courses (Klein, 2002). Elementary and secondary mathematics texts attempted to promote understanding of mathematical concepts as well as procedures, more rigorous standards for student learning were developed, and teaching methods attempted to engage students in the same processes mathematicians engage in (Woodward, 2004).

These efforts to revamp science and mathematics curricula while creating a new generation of scientists and mathematicians ran out of steam in the early 1970s (Klein, 2002; Shamos, 1996). Although the math curricula, often referred to as “New Math,” focused on student understanding and logical explanation, they were widely criticized because their approaches varied dramatically and teachers found them difficult to use (Klein, 2002;

Woodward, 2004). Similar criticism was leveled at the new science curricula, and these well intentioned efforts to enhance science and mathematics instruction were deemed failures (Klein, 2002; Shamos, 1996).

In the early 1980s the movements were superseded by the Back to Basics Movement. Extracurricular activities such as art and social services were seen as less important than reading, writing, and arithmetic, and were pushed aside. Mathematics education on this movement was considered to be "highly formulaic" and was characterized by whole-class instruction that taught specific processes for obtaining a specific product or correct answer (Woodward, 2004, p. 22). Science education at this time "floundered in a sea of uncertainty" (Shamos, 1996, p. 45) as criticism of the effectiveness of previous programs led to decreasing support for science education.

The Back to Basics movement was interrupted with what appeared to some to be an educational crisis—student achievement in the United States was decreasing, and in some cases, was lower than that of other industrialized nations (Shamos, 1996). One report in particular, *A Nation at Risk* (1983) raised concerns about the state of math and science education, calling attention to teacher shortages and a resultant drop in mathematics and science teacher quality (Klein, 2002). This new reform, generated by government leaders, scientists, mathematicians, and educators, called for standards to guide teachers with the goal of increasing learning in mathematics and science for *all* children, not just those who appeared suited to become mathematicians and scientists, as was the case with the New Math movement. *The Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics (NCTM), 1989) set high expectations for all students in mathematics. Similarly, the *Science for All Americans* (American Association for the Advancement of Science (AAAS),

1990) sought to prepare all students to function more fully in society as a result on an enhanced scientific literacy, a greater understanding of science, and the ability to apply science to social experiences (DeBoer, 1991; Shamos, 1996).

Interestingly, and not entirely coincidentally, the high stakes assessment movement, which seeks to establish high levels of accountability for all students, has followed on the heels of the efforts to improve the mathematical and science learning of all. Since 2001 and the passing of the *No Child Left Behind Act (NCLB),* students annually participate in standardized testing. NCLB, with its requirements for adequate yearly progress, has increased accountability for teachers, raised expectations for student performance, and encouraged the research community to produce "evidence-based practices" (Cantrell, 2012, p. 55). The preponderance of standardized test data (e.g., NEAP, TIMSS, and PISA) in the U.S. has facilitated international comparisons of student performance, and has revealed a gap between the performance of U.S. students and the students of other first world countries, thus heightening concern among all stake holders (National Center for Education Statistics, n.d.; OECD, 2010; Scott, n.d.). The urgency to close this gap has fueled the fires of mathematics and science education reform, under the STEM banner. The STEM education reform movement enhances mathematics and science education reforms with an increased emphasis on technology and engineering. These latter disciplines provide opportunities for meaningful application of scientific and mathematical skills and knowledge which increases student performance in science and mathematics and prepares students for careers in all four STEM disciplines (Carr & Strobel, 2011; Gallant, 2011; Sanders, 2009).

Preparing students for STEM careers requires consideration of current patterns and realities associated with careers in the STEM disciplines. Currently, work in these disciplines is characterized by *convergence,* professionals in multiple disciplines combining specialized knowledge to solve current and future problems. This term, coined by the Boston Massachusetts Institute of Technology in *The Third Revolution: The Convergence of the Life Sciences, Physical Sciences, and Engineering*, (Sharp, 2011) illuminates the ingenuity and collaboration needed to achieve recent scientific, technological, and engineering advancements. To illustrate convergence, consider advancements in biomedical imaging. The laser imagining technology commonly used to detect various diseases and bone injuries is now being used to fight eye disease and in particular, allows a way to diagnose eye diseases that lead to blindness. This technology resulted from the collaborative efforts of those with expertise in physics, optics, electrical engineering, and physiology (Sharp, 2011). Therefore, teachers should provide authentic learning experiences that mimic the patterns and realities of work in the real world. An integrated curricular approach in STEM education could help students develop an integrated knowledge and skill set, and prepare them for future careers and societal responsibilities where convergence is the norm.

Politicians and researchers describe characteristics of STEM integration in education. The National Governor's Association (2007) said "One hallmark of a STEM classroom is an emphasis on design and problem-solving in 'intellectually messy' learning situations that weave together the disciplines through topics such as nanotechnology, biomedical engineering, and astrobiology" (p.7). Morrison (2006) claims that the STEM student should be a problem solver, innovator, inventor, and a logical thinker. He/she should be self-reliant, technologically literate, and able to relate culture and history to education. The STEM classroom should be student-centered, serving students with varying learning styles. The classroom, a center for invention and innovation, should contain tools and technology to support spontaneous questioning and planned investigations. Mason writes that “introducing students to the forms of discourse and inquiry associated with the disciplines and the subject matter areas can provide them with valuable mechanisms for making sense out of a complex world” (1996, p. 264).

Issues concerning STEM Integration

As researchers and educators search for ways to provide and implement an integrated curricular approach in STEM education, issues such as varying existing understandings of integration and described characteristics of STEM integration should be considered.

Varying understandings of integration. Arguments for and against integrated stem education can be viewed with the broader notion of curriculum integration, which has been a topic of discussion in educational literature for more than 100 years. Many authors publish arguments supporting and calling for curriculum integration, while others bring up concerns and weaknesses of the educational approach (Czerniak, 2007).

There are several arguments made in support for including curriculum integration within K-12 education. The simplest argument is that curriculum integration is practical because it follows patterns of how disciplines are integrated outside of an educational setting. Mason (1996) writes that the world today is complex and technologically advanced, and those best prepared for it possess an interdependent set of skills and knowledge that capitalizes on connections among disciplines. He views integrated curriculum as a way to prepare students for the world they live in, as opposed to the traditional form of education preparation—the factory model, where students travel from classroom to classroom receiving instruction in isolated disciplines. Hurd (1991) similarly argues that the disciplines of science and technology are currently merging into an integrated system and that integrating the disciplines in school is vital to preparing students to work in the future.

Advocates supporting curriculum integration also claim that integration is a powerful motivational tool. "An integrated, inquiry-oriented curriculum potentially offers many occasions for students to develop and refine meaning knowledge and skills" often resulting in increased self-efficacy and motivation (Mason, 1996, p. 265). Zhbanova, Rule, Montgomery, and Neilsen (2010) compared integrated content lessons to traditional direct instruction lessons. They report results of students involved in integrated lessons receiving more positive feedback from teachers on work during class time than students who participated in traditional direct instruction lessons, which appeared to lead to an overall more pleasant mood in classrooms and higher levels of student motivation. They also argue that integrative lessons sometimes require teamwork to solve a problem, thus encouraging shared learning experiences and providing motivation to collaborate. Stipek (1993) and Ainley (2006) suggest that integration between subjects presents opportunities for student choice resulting in motivation for learning. Studies including integration have led to improvement in scores on national and state tests for students with educational disadvantages, minority groups, and bilingual students (Czerniak, 2007; Greene, 1991; Zwick & Miller, 1996).

A third argument in support of curriculum integration is improvement in student achievement. Curriculum containing integration naturally allows students to form deeper understandings, have more profound grasps of concepts, and create a "big" picture among disciplines (Brooks & Brooks, 1993; Perkins, 1991).

In contrast, there are some concerns among researchers and educators with curriculum integration. Some researchers are concerned that abandoning the traditional separation of disciplines and integrating content may leave "wide gaps in students' understanding of important concepts and subject matter" (Mason, 1996, p. 263). Others are concerned with the level of expertise that is needed by teachers to successfully plan, implement, and manage lessons and units of instruction that are of an integrative nature. Likewise, more teacher preparation time is necessary to identify meaningful, interwoven subject connections that support learning goals (McBride & Silverman, 1991; Zhbanova, et al., 2010).

A final concern presented in the research is the lack of an agreed-upon definition of curriculum integration, specifically in terms of how that integration is enacted in classroom settings. Integration is conceptually and operationally defined in varied ways. Mason states, "integrated curriculum involves elements from more than one discipline and somehow relates to a problem, theme, or situation from the real world" (1996, p. 264). Satchwell and Loepp (2002) describe three different approaches for designing classroom curriculum that creates connections between multiple disciplines. These approaches include: (a) *intradisciplinary* curriculum, focus "on integrating of different areas within one discipline;" (b) *interdisciplinary* curriculum, "focus on instruction within one domain, while supporting the content with implicit connections between disciplines;" and (c) *integrated* curriculum, "one with explicit assimilation of concepts from more than one discipline" (p. 42). Hurley (2001) sheds light on the confusion with defining integration, even when just focusing on science and mathematics. In reviewing publications on the matter he found the presence of "five major types of integration: sequenced (science and math planned and taught one preceding the other); parallel (science and math planned and taught together); partial (the subjects are taught separately as well as integrated); enhanced (one of the subjects is the major discipline being taught and the other is added to enhance the other); and total (science and mathematics are taught equally together)" (p. 263).

The confusion about what defines or qualifies as integration is not only found among curriculum experts, but also among classroom teachers. A survey study given to a population of middle school science teachers revealed that teachers' responses did not contain common characteristics for integration (Stinton, Harkness, Meyer, and Stallworth, 2009). Another study designed to better understand teacher perceptions and practices in STEM integration found that teachers in different STEM disciplines have different classroom practices, because of their different perceptions about STEM integration (Wang, Moore, Roehrig, and Park, 2011).

Characteristics of STEM integration. Although the education community lacks a specific, detailed definition of integration, it is obvious that the goal of integration is to achieve greater student learning in more than one discipline or content area. As mentioned before, STEM education reform looks to improve student learning in science and mathematics, therefore, it seems logical that integration of the STEM disciplines may be beneficial. A clear definition of integrative STEM is needed to provide a foundation for research in this area. Sanders (2009) describes integrative STEM as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas," (p. 21) but argues that true integrated STEM requires technology or engineering to be the focus of integration with another subject (Brunsell, 2011). This definition calls for a change in the curriculum integration of STEM disciplines as we move away from what educational research has already proclaimed about math and science integration and search to find what integrative STEM, with a focus on technology and engineering, has to offer.

The point to focus on the "T" and "E" within STEM education is also recognized by the National Academies Press in their new document, *A Framework for K-12 Science Education* (National Research Council (NRC), 2012). The document introduces a new expectation for education—engineering content and process should be taught to all students as well as science content and processes. The document also clarifies definitions for the terms *engineering* and *technology* in an educational context. Engineering is defined broadly as "any engagement in a systematic practice of design to achieve solutions to particular human problems" (p. 11) and technology means "all types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communications devices" (pp. 11-12). The Framework's overarching goal is that all students will have developed an appreciation for and knowledge of science and engineering content and processes by the end of their public education.

Research about STEM Integration within Education

Two approaches in Integrative STEM curriculum development and instructional design have gained prominence—Problem-based Learning and Integrated Units of Instruction. This section will further describe each approach and research regarding the effects attending to student learning.

Problem-based learning. Problem-based learning (PBL) is defined as "focused, experiential learning organized around the investigation, explanation, and resolution of meaningful problems" (Hmelo-Silver, 2004, p. 236). This pedagogical approach (Etherington, 2011) involves students working in a collaborative group as active learners while the teacher acts as a guide to facilitate student learning. It allows for students to acquire new information on specific content as well as develop critical problem solving skills that will aid them in lifelong learning. Another important aspect of PBL is that it facilitates the integration of knowledge from related disciplines, thus its connection to STEM integration. This method of instruction, designed by the McMaster University Faculty of Health Sciences, was first implemented in medical schools in the 1970s. Success of the Problem-based learning courses has led to its use throughout all levels of K-16 education (Barrows, 1996; Hmelo-Silver, 2004). Many strengths of PBL include increased retention of information, the development of lifelong learning skills, early exposure to real-life experiences, increased student-teacher interaction, and an increase in motivation (Klegeris & Hurren, 2011).

As often seen in educational reform, research is done within multiple settings in hopes of identifying best practices for implementation in the classroom setting. Such is the case for educational research on the effects of integrating STEM disciplines through problem-based learning as studies have been conducted in university courses, professional development courses for K-12 teachers, and K-12 classrooms. Klegeris and Hurren (2011) conducted a study in which biochemistry and physiology were integrated through problem-based learning in an undergraduate course at University of British Columbia Okanagan. The number of students enrolled in the course was higher than usual, and the aim of the study was to see the impact of PBL in a large classroom setting. PBL activities were offered as a supplement to the traditional lectures planned for the course. Through surveys students who participated in PBL reported more motivation to attend and participate as well as attaining a better understanding of content when compared to learning content in class lectures.

Felix and Harris (2010) developed a problem-based curriculum for a two-week Summer Science Institute for K-12 teachers. This professional development program, funded by a federal Math Science partnership grant, integrated content from all STEM disciplines with an emphasis on engineering design while challenging teachers to construct a model of a solar house. In reporting the findings obtained from a study of the program, Felix and Harris stated, “knowledge of science concepts, cooperative learning in science or math, and project-based learning in science or math were among the top components rated ‘greatly increased’ by teacher participants” (2010, p. 33).

Another program, *Design-based Science* (Fortus, et al., 2005)*,* used problem-based learning to integrate science and engineering in a ninth grade classroom. A study of the program (Fortus, et al., 2005) was conducted in order to determine if students who participated in the PBL instruction would transfer new science knowledge and problem solving skills to an authentic, real-world problem. All participants were given a pre-test and a transfer task, followed by participation in the integrated instruction and a post-test. Results revealed a stronger correlation between the scores of the post-test and the transfer task than with those of the pre-test and the transfer task. An increase in interest levels in science, technology, engineering, and mathematics was also observed.

Another integrated curriculum program, *Learning by Design* (Kolodner, 1997) has also been developed for middle-school science classrooms based on the principles of problem-based learning. Physical and earth science instruction is integrated with engineering and mathematics instruction as students are required to build and design devices that attend to forces, motion, and natural earth processes. Students are also given more opportunities to reflect on their own learning. Researchers (Kolodner, et al., 2003) found that students involved in this program became more interested in the work of their peers and more motivated to ask questions than students not involved in Learning by Design. Teachers were better able to uncover misconceptions about content than comparison teachers not involved in the program.

Diaz and King (2007) adapted a post-secondary engineering curriculum and applied it to teaching mathematics in the elementary grades, creating a pre-engineering program called *Math Out of the Box*. This program encourages inquiry-based learning by focusing on the use of innovative tools and manipulatives to complete tasks that attend to both engineering and mathematics. The program was implemented in third grade classes at four different elementary schools in South Carolina. The remaining schools across the state, using various mathematics curricula, did not participate in the program and were used as a comparison group for the study. Findings show that third grade students in the *Math Out of the Box* program had higher levels of achievement in mathematics than third grade students who were not in the program.

These studies show that research in STEM integration through Problem-based learning may have an effect on increasing student achievement in the STEM disciplines and also increase student interest levels and motivation for participation.

Integrated units of instruction. An integrated unit of instruction contains objectives for student learning in more than one discipline. The process of assimilation of concepts or objectives starts with identifying themes within concepts from different disciplines and making connections between those disciplines. After connections are made, instructional planning of specific lessons and learning activities for the integrated unit occurs (Cantrell, Pekcan, & Itani, 2006; Carr & Strobel, 2011; Cunningham, Lachapelle, & Hertel, 2012; Satchwell & Loepp, 2002). This method for integration within STEM education differs from the Problem-based Learning approach because content connections within disciplines are formed around a theme or concept, not a problem needing to be solved.

Research on integrated units of instruction, like research on PBL, has been conducted within K-12 classrooms. At the middle school level, Satchwell and Loepp (2002) designed, developed, and implemented an integrated mathematics, science, and technology curriculum for middle school students. They found the integrated curriculum was accompanied by benefits to students such as connecting concepts across disciplines, greater motivation to learn, and higher scores on measures of science and mathematics performance than students enrolled in traditional programs. The study also reported teachers' concerns with this type of curriculum including complex level of development, scheduling of teacher planning time and resources, and teacher's pedagogical ability to facilitate instruction and management. Therefore, more research is needed in this area to support teachers with implementation of integration. Cantrell, Pekcan, and Itani (2006) designed engineering challenges, projects with specified constraints, for middle school students that included goals for helping students engage in processes that required the use of scientific methods. The researchers developed a learning model for integrating engineering with physical science throughout the challenges and found that adapting the method of using engineering design challenges to a middle school level met the needs and interests of middle school students as they had to understand and apply science content in order to succeed in the engineering challenge. Student learning was assessed through teacher designed tests, state CRTs and individual interviews. Data collected indicated a decrease in the achievement gap between minority groups and majority groups through student scores on teacher designed tests and interviews, but not on state CRTs.

K-12 research about integrated unit implementation has also been conducted in elementary classrooms (Burghardt & Knowles, 2006; Penner et al., 1998; Wendell & Lee, 2010). First and second-grade students learned about the bone and muscle makeup of an elbow through the integration of an engineering design task where they each had to create a model of an elbow and then evaluate the model in terms of its function like a real elbow (Penner et al., 1998). Students were later given the chance to redesign another model attending to function and not just perception. The study showed that the students' understandings of the models were comparable to fourth and fifth grade students' understandings (Penner et al., 1998). Science and engineering were integrated in a third grade classroom as students were given engineering designs task to complete in testing building structures, thus allowing them to classify building materials according to their strength. Results showed that students significantly improved on both tasks given during post instruction interviews compared to pre instruction interviews (Wendell & Lee, 2010). Burghardt and Knowles (2006) used engineering design strategies integrated with mathematics when teaching fifth grade students and saw a significant positive change in the student attitudes towards mathematics.

Engineering is Elementary (*EiE*) is a curriculum developed by the Boston Museum of Science that has been developed, tested, and studied since 2004. This curriculum development began with a search to understand student and teacher conceptions of and ideas about engineers and the process of engineering (Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Faux, 2006; Knight & Cunningham, 2004). Once student and teacher conceptions and ideas were found, multiples research studies were designed and implemented to see if conceptions and ideas could change through participation in the EiE curriculum. Findings from these studies report that participants in EiE curriculum had greater ability to understand what items qualify as technology—beyond the general view of something electronically powered, had better understandings of the design cycle engineering process, presented a better understanding of engineering careers and the tasks therein, and an increased understanding of science content involved within the unit, and did significantly better on post-test assessments than students not involved in the curriculum (Jocz & Lachapelle, 2012; Lachpelle & Cunningham, 2007; Lachapelle, Cunningham, Oware, & Battu, 2008). These studies all show that integration may have a positive impact on student attitudes toward STEM subjects or may increase student understanding within those subjects, but much more research about curricular integration within STEM is needed, especially at the elementary level.

Throughout the research previously described, with the exception of the EiE research, there is also a lack of detailed instructional and curricular design for STEM integration. This study suggests that literature available on practices used within science and engineering can be used to create possibilities for pedagogical integration through Problem-based learning. EDC and 5E are both attempts to help teachers guide children through projects that mimic authentic scientific or engineering work. The process of scientific inquiry known as 5E (Bybee et al., 2006) occurs in stages: engage, explore, explain, extend, and evaluate and EDC, or the Engineering Design Cycle, (Asunda & Hill, 2007) is a series of steps that engineers follow to solve a problem: plan, build, test, improve, and retest. Therefore, although not instructional models in the fullest sense of the term, they are important guides in instruction for science and engineering.

This section will explain one of many possible ways for integration. In the e*xplore* phase of the 5E science inquiry model students are provided with experiences that allow facilitation of conceptual change. Current content knowledge, skills, and processes previously known to the students can be identified and used to "generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation" (Bybee et al., 2006, p. 2). The nature of the explore phase is similar in design and purpose to the Engineering Design Cycle (Asunda & Hill, 2007). In e*xplore,* students can be given a science question and work to find answers to that question and learn new science content. In EDC, students are given a problem and expected to use their science content knowledge to design, construct, and test a possible solution to the problem within certain constraints. This design cycle can repeat multiple times in order to allow students to apply and implement new knowledge as they redesign a new solution. New knowledge of science content comes from the continuation of the 5E inquiry model through the *explanation* and e*laboration* phases. The e*xplanation* phase provides opportunities for students "to demonstrate their conceptual understanding, process skills, or behaviors" and for teachers "to directly introduce a concept, process, or skill" (Bybee et al, 2006, p. 2). This phase is followed by the *elaboration* phase where "teachers challenge and extend students' conceptual understanding and skills" (p. 2). In the *elaborate* phase students can apply their understanding of the concept by engaging in additional science activities, or in an integrated situation, students can elaborate by improving and re-designing their solution to the problem presented in the engineering design challenge. Reinforcement for learning the science content occurs as students use knowledge to aid them in the engineering design challenge. Integration of both engineering and science practices are needed to accomplish the task and solve the presented problem.

This possibility of integrating pedagogy for science and engineering gives powerful meaning to students as well as a more representative view of the true nature of both disciplines in terms of how they coincide in real world situations. Engineering is meaningless without a purpose or a problem to solve. The problems brought to engineers are often rooted in science content. Scientists observe and question the world around us, but do not always have the means to answer questions or solve problems without the help of engineering. Allowing students authentic learning through the integration of science and engineering content and pedagogy in a science unit of instruction may have an impact on student learning.

In summary, existing literature on STEM integration lacks research at the elementary level, including details on specific instructional design and curricular planning design and the implementation thereof. This study suggests that a detailed instructional design plan could be obtained through integration of known pedagogical practices used in engineering and science education. This study may also discover positive impacts on student scientific learning as well as attitudes or interests in science and engineering.

Chapter 3

Methodology and Procedure

The purpose of this study was to investigate the effects of integrating two of the STEM disciplines, engineering and science, on student achievement in an elementary school classroom. This was done by creating an integrated science and engineering unit of instruction and measuring outcomes in student achievement. More specifically, this study focused on the effects integrating engineering content and pedagogy into science pedagogy had on supporting student understanding of science concepts.

Participants

The two fourth-grade teachers involved in this study were comparable in teaching experience and in teaching style. Both teachers were female, in their twenties, and received their elementary education degrees from the same private university. Both were in their first five years of teaching and had been involved in the same school district mentoring program. Management procedures implemented by the teachers were similar in both classrooms and encouraged the same respectful behavior of students and as well as an overall safe learning environment.

The students participating in the study were fourth-grade students (n = 66) at the same elementary school in a suburban community in the Intermountain West. They were enrolled in the classes of the teachers described above. A total of 788 students were enrolled in this elementary school whose population was not as diverse as other schools located nearby in the same school district. The majority of students (94%) were Caucasian. Many of these students came from families with medium to high socioeconomic status. Many families had multiple children attending this school, and their parents were very involved in the school and in the community. Parent volunteers and technicians (adults qualified by the school district to aid teachers) offered assistance to teachers on a daily basis. There were 134 students who qualified for free and reduced lunch, and 16 % of the students were enrolled in and received special education services.

The student populations of both fourth-grade classes had similar characteristics. There were 33 students in one class and 33 students in the other. All the students were ages nine or ten and many of the students had been attending this elementary school since kindergarten.

Differences in the fourth-grade classes included the number of students who received special education services and the number of students enrolled in the gifted and talented program. The classroom assigned as the treatment group, or the integrated classroom, had 17 female and 16 male students. There were three students who received special education services and seven students who participated weekly in a gifted and talented program. All the students in the class were Caucasian. The control group, or the traditional classroom, had 17 female and 16 male students. No students were enrolled in special education and five students were enrolled in gifted and talented. One student in this class was of African American ethnicity and two were Asian (see Table 1).

Table 1

Classroom Demographic Percentages

Demographics	5E Classroom (Control)	Integrated Classroom (Treatment)
Gender		
Male	52%	52%
Female	48%	48%
Special Education	0%	9%
Race		
Caucasian	91%	100%
African American	3%	0%
Asian	6%	0%

Unit Design

The following section explains procedures used for designing and teaching the integrated and traditional units of instruction as well as assessing student learning within those units. The steps for design are explained in the same sequential order that the teachers followed.

Concept statements. Unit design began with the two teachers working together to identify science concepts to be taught during the science units of instruction. The two units of instruction studied, Utah Environments and the Water Cycle, were both included in the fourth-grade science core curriculum provided by the state. This curriculum was used to flesh out the specific concepts that were the focus of these units. Once the science concepts were identified, the teachers developed 8-10 primary concept statements for each unit. A concept statement is a topic sentence containing information about a specific piece of content knowledge or skill that students are expected to learn within a unit of instruction and are used by teachers to guide planning of assessments and instruction. Primary concept statements may be sub-divided into secondary concepts if needed.

Assessment. Backwards design (Wiggins & McTighe, 2005) was the second step in the development of the units of instruction. This design strategy advises that the assessments for each unit of instruction will be developed first, and then followed by the development of instructional activities. Using the science concept statements, the teachers used a test blueprint to develop a test to be administered to students at the end of each science unit. Both the Utah Environments test and the Water Cycle test addressed all the information included within the science concept statements and enabled teachers to assess how well the science content was learned by the students.

Table 2 is a test blueprint that provides structure for the items (i.e., questions) on a test. This table is used to chart the basic elements of a test: content knowledge, cognitive levels of thinking, and item type. Using a test blueprint helps to ensure alignment and content validity (Cantrell, 2012). A test blueprint also confirms that all content areas taught within a unit and multiple levels of understanding are being assessed within a test. This is done by specifically focusing on the content and cognitive domains mentioned above. Each of these domains is to be further divided into sublevels and considered carefully by the creator of the test blueprint.

Following the classification of content domains the creator of a test blueprint must consider the cognitive domain. The cognitive domains have been identified by the TIMSS 2011 Science Framework as containing three different sublevels. These sublevels are knowing, applying, and reasoning. Each of these levels has been carefully defined in the TIMSS assessment and appropriate percentages for testing have also been determined (TIMSS, 2011). These sublevels are added to the table for the test blueprint and adjusted until the appropriate percentages are met for both the content and the cognitive domains. Once the test is completed each test item can be analyzed in terms of the content learned and the cognitive level of thinking achieved. This provides many new opportunities in terms of measuring student performance at the end of the unit of instruction.

Instruction. After the end-of-unit tests were developed, the science concept statements were used to guide instructional planning. Each concept statement became the topic of focus for one lesson within each science unit. Both teachers collaborated to plan lessons for the Utah Environments unit and the Water Cycle unit that taught the science content using the same science pedagogy, the 5E instructional model for teaching science through inquiry (Bybee & Van Scotter, 2007). One classroom teacher integrated engineering pedagogy, the engineering design

Table 2

Test Blueprint

Item	Content Knowledge	Cognitive Level	Item Type
1	Important	Knowing	Matching
2	Important	Knowing	Matching
3	Enduring	Knowing	Matching
4	Enduring	Knowing	Matching
5	Enduring	Knowing	Matching
6	Enduring	Applying	Multiple Choice
7	Familiar	Knowing	Multiple Choice
8	Enduring	Reasoning	Multiple Choice
9	Enduring	Reasoning	Multiple Choice
10	Familiar	Applying	Multiple Choice
11	Familiar	Applying	Multiple Choice
12	Enduring	Reasoning	Multiple Choice
13	Important	Applying	Multiple Choice
14	Important	Knowing	Multiple Choice
15	Important	Knowing	Multiple Choice
16	Enduring	Applying	Multiple Choice
17	Familiar	Applying	Short Response
18	Enduring	Applying	Short Response
19	Enduring	Reasoning	Short Response
20	Important	Applying	Short Response

cycle, with the science pedagogy (5E) to teach the science content of the Water Cycle unit.

As discussed in the previous chapter, curriculum integration must be justified in terms of instructional approaches and meaningful content connections. A natural overlap can be found in the design structures of each of the above mentioned instructional approaches or pedagogies justifying integration. Similarly, connections between science and engineering content justify integration in the Water Cycle unit. The science content in the Water Cycle Unit contains information about three processes, evaporation, condensation, and precipitation, which naturally occur to cleanse Earth's water along with information about how the water cycle can affect a community's water supply. Engineering content consists of processes used to solve problems. One specific process used by engineers is the Engineering Design Cycle (EDC). Since engineering is a skills based content area that draws upon important science content, this integrated unit will connect the engineering process to a science problem about the Water Cycle.

For example, one of the science concepts that students learned was "the water supply of a community is affected by the water cycle." What if the water supply in a community was contaminated? This would create a science problem for engineers to solve. Students were given this engineering design challenge: "Imagine the water in your community is contaminated by a mud slide. Design a water chamber that *uses the water cycle* to produce safe drinking water." Students then designed, constructed, and tested a water chamber. This design challenge was an opportunity for students to showcase previous knowledge they had of the underlying, inherent science content as well as an opportunity for teachers to assess student knowledge and uncover misconceptions. Following the first testing stage, students were given the opportunity to redesign their solution. This *redesign* stage occurred simultaneously with opportunities to learn science content and may have influenced their engineering plans. Science content was taught using the 5E model of inquiry and included information on the processes of the water cycle: evaporation, condensation, and precipitation. Thus there was a logical connection between using the engineering design challenge to obtain clean water and the water cycle science content which means within the revisiting of the EDC there is a natural way of also revisiting the underlying, inherent science. Implementation of the integration of both 5E and EDC required the teacher to think through possible student thinking throughout the process of lesson planning while also finding connections to reinforce how 5E and the EDC coincide.

The EiE curriculum, mentioned in the previous chapter, was used in this study by one classroom teacher as a resource containing the engineering pedagogy that was integrated within science pedagogy. The curriculum was designed to focus on a field of engineering and teach students about the processes and purposes of engineering within that given field. Developers of this curriculum acknowledge that engineers need knowledge of both science and math content areas in order to solve problems and specifically address this idea through using engineering as a tool to reinforce learning of science content. Two goals of the EiE curriculum are: “Increase children’s technological literacy and increase educator’s abilities to teach engineering and technology” (Lachapelle, 2008, pp. 1-2). The museum hopes to reach these goals by providing teachers with detailed background knowledge, detailed lesson plans, questions to guide student thinking, as well as the needed materials for each lesson and activity.

Research Design

The purpose of the study was to explore how an integrated science and engineering unit may affect student learning in terms of student performance on end-of-unit tests and student attitude and interest in science. To achieve this purpose, a quasi-experimental design was selected because participants were not randomly assigned to control and treatment groups and because the elementary school classrooms were not randomly selected for either control or treatment (Creswell, 2008). A common type of quasi-experimental design used in educational research is the Nonequivalent Pretest-Posttest Control Group Design (McMillan & Schumacher, 1984). In this design two groups are studied, one of which receives a treatment. The control and treatment groups are considered "nonequivalent" because the groups are not completely equal (Trochim, 2006). Improvement in student learning is found by comparison of student performance on a pretest to the student performance on a posttest. Both pre and posttests are designed to test on the same material, thereby showing possible effects of the treatment.

This research study implemented a modification of the Nonequivalent Pretest-Posttest Control Group Design, the modification being that the Pretest-Posttest comparison was substituted with a Posttest-Posttest comparison as shown in Table 3. The two groups studied, two fourth-grade classrooms, qualified as nonequivalent groups because they varied in multiple ways, including male/female ratio, student interests and student abilities. Both groups were taught the same science content in the first unit by two different teachers using the same 5E methodology and completed the same end-of-unit test (Posttest 1). The same was true for the second unit except the treatment group received an integration of science and engineering pedagogy while the control group was taught using science pedagogy only. After being taught the second unit, all students in both groups completed the same end-of-unit test (Posttest 2). Posttest 1 and Posttest 2 are displayed in Appendix A and Appendix B, respectively. Another representation of this design is shown in Figure 1.

Using this research design required that attempts be made to control for extraneous variables. Procedures for designing the units of instruction and posttests were outlined and both teachers of the treatment and control groups collaborated throughout this process. The unit design, lesson planning formats, and the assessments were the same for both treatment and control groups. The individual teachers of those groups may have had differences in teaching style that may have affected student learning. Differences in student achievement outcomes based on teacher personality and student background is known as *teacher effect* (Konstantopoulos, 2011; Muijs, 2003). The comparison of the treatment and the control groups after Posttest 1 will allow analysis to determine if a teacher effect is present and allow for control for that variable.

Table 3

Treatment in the Nonequivalent Posttest-Posttest Control Group Design

Groups	Science Unit 1 Posttest	Science Unit 2 Posttest
Treatment	5E Model	5E Model + Engineering Design Cycle
Control	5E Model	5E Model

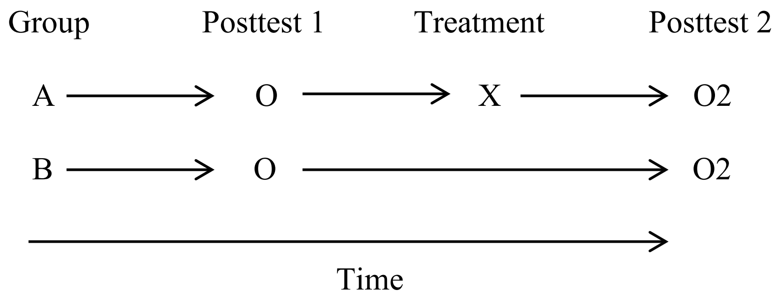

Figure 1. Quasi-experimental design in which two groups are studied over time, while only one receives the treatment.

As mentioned in Chapter 1, the research questions I sought to answer were:

1. What effect does integrated science and engineering content and pedagogy have on student performance and student attitude and interest in science?
2. How does that student performance vary across measures that differ as to cognitive level?

In order to answer the research questions, data sources were needed to collect information on student science achievement. The end-of-unit tests served as quantitative data sources for students in both the treatment and control groups and were designed through the use of a test blueprint— as outlined in detail in the above section, Unit Design.

Because of the small population in this study, another form of data collection was used to measure impact of student learning in addition to the two end-of-unit tests. The researcher of this study recognized that measuring learning through end-of-unit tests can reveal the amount of content mastered by a student, but also recognized that learning can occur in the form of a change in attitude or interest toward a specific discipline. Many of the studies presented in the literature review reported on student motivation, attitudes, perceptions, and interests in STEM disciplines (Burghardt & Knowles, 2006; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Jocz & Lachapelle, 2012; Knight & Cunningham, 2004; Satchwell & Loepp, 2002). Some may argue that this issue is just as important for educational reform as implementing new teaching practices. With this concept of learning in mind, an open-ended attitude/interest survey (see Appendix C) was given to the students immediately following their completion of each end-of-unit test. This survey was administered to both the treatment and control groups and used to identify attitudes toward and interests in scientific learning throughout the study. Each group was given the same survey at the end of instruction and assessment for the second unit.

Responses from students participating in the treatment group were compared to the student responses from the control group.

The survey was created by the researcher and designed to be simple enough for a fourth-grade student to read and understand independently. The survey contained five open-ended questions that were written with the goal of gaining insight into student attitudes toward and interests in science instruction. Before administering the survey, its validity was established in two ways. First, possible student interpretation of questions and possible responses were taken into consideration during development in hopes of creating a valid survey. Secondly, three students from each class were interviewed and asked to interpret each survey question aloud to determine if their interpretations matched those of the researcher. During the interviews two students needed clarification before they could interpret questions one and two. Because of this a change was made in the survey—the phrase "this unit" was changed to "Water Cycle unit." At that revision, the following interviews were successful and the interpretations of the students matched the researcher.

Data Analysis

Scores on the end-of-unit test for the first science unit of instruction, Posttest 1, were compared to the test scores of the second unit of instruction, Posttest 2. The scores from Posttest 1 were first analyzed by a *t*-test to compare the means of the treatment and the control group, determining the presence of a teacher effect. It was assumed that if there was no statistical significance between the means of the two groups, then there was no teacher effect and a *t*-test would be used for analysis of student scores on the second unit test, Posttest 2.

If a statistically significant difference was found between the means of student scores obtained from the treatment and the control groups during analysis of Posttest 1 then another method for statistical analysis was planned to be used to analyze the data from Posttest 2. The means from Posttest 2 were compared using analysis of covariance with scores obtained from Posttest 1 as the covariate. Students may have done better on just the test items that relate to the part of the unit that included engineering, but there may have been enough connection between all the science concepts that inclusion of engineering might have affected performance on all the test items.

To answer the second research question test items for Posttest 2 were analyzed in terms of their cognitive domain—knowing, applying, and reasoning. This information was available through the use of a test blueprint which guided the participating teachers in their test development. A series of *t*-tests were performed to compare student responses from both the control and treatment group on test items to see if there is a significant difference on questions with varying cognitive domain. An analysis of covariance test was also run on each level of questions to determine any differences.

Effect size was planned to be calculated if statistical significance was found. To determine effect size, a ratio was computed between the Posttest 2 differences and the pooled standard deviation of the Posttests (Ellis, 2010). This ratio allowed determination of the magnitude of the treatment and to see if the difference between the treatment and the control groups was meaningful (Salkind, 2008). Generally an effect size of 0.2 is considered small, 0.5 is considered moderate, and 0.8 is large (Cohen, 1988).

The qualitative data collected through the attitude/interest survey was analyzed through a coding process in an effort to find common themes across groups (Creswell, 2008). The quality and quantity—cognitive complexity and the nature of the language used—of student responses relating to these emerging themes for each group was compared.

Chapter 4

Findings

The purpose of this study was to answer two research questions:

1. What effect does integrated science and engineering content and pedagogy have on student performance and student attitude and interest in science?
2. How does that student performance vary across measures that differ as to cognitive level?

The first section of this chapter, Integrated Instruction and Student Performance in Science, addresses questions one and two through the presentation of the quantitative data analysis. The second section of this chapter, Integrated Instruction and Student Attitude/Interests, addresses question one through qualitative data analysis. Students enrolled in two fourth-grade classes, constituting the control and treatment groups, at an elementary school in the Intermountain West participated in this study. There were 33 students in both the control and treatment groups. To investigate both research questions regarding the effectiveness of an integrated unit of instruction on science content learning quantitative research methods were used. A non-integrated science unit was taught to both groups and an end-of-unit test (Posttest 1) was administered first to determine any statistical differences between classes that could be due to teacher effect. A second posttest was administered to both groups following the second unit to measure instructional effects.

Integrated Instruction and Student Performance in Science

Student raw scores were converted to percentages. The means obtained from administering the first posttest to both classes were compared using a *t*-test for independent samples. No statistically significant difference was found at the .05 level, *t*(66) = .379, p = .706, df = 64. Because this analysis of scores revealed no teacher effects, a *t*-test was also used to compare the means of the two classes on the posttest. The results of this *t*-test also revealed no statistically significant difference at the .05 level, *t*(66) = 1.065, p = .291, df = 64. Effect size estimates were not calculated in view of the absence of statistically significant differences. Due to the fact that the treatment group received the additional integrated engineering instruction, which required students to apply learned science content, the results were surprising.

Further analysis to answer the second research question was performed on categories of test items from both posttests. The end-of-unit tests (Posttests 1 and 2) were created using a test blueprint which required the test to meet certain parameters pertaining to cognitive domains of thinking—knowing, applying and reasoning. Test items were categorized based on the cognitive domain used to answer the question. For the analysis, a series of *t*-tests were run to compare performance of students in the control and treatment groups on categories of items to test for the presence of significant differences. Results show that there were no statistically significant differences as shown in Table 4. Again, no effect size estimates were calculated.

Table 4

Descriptive Statistics for Varying Cognitive Levels

	Posttest 1						Posttest 2				
Group	*n*	*M*	SD	*t*	p	df	*M*	SD	*t*	p	df
Knowing											
Treatment	33	87.12	17.26	0.00	1.00	60.64	88.18	13.36	0.74	0.47	63.96
Control	33	87.12	13.58	0.00		64.00	90.61	13.01	0.74		64.00
Applying											
Treatment	33	75.76	18.70	-0.39	0.70	63.53	82.42	15.38	1.75	0.09	56.73
Control	33	74.02	17.15	-0.39		64.00	88.18	10.58	1.75		64.00
Reasoning											
Treatment	33	71.21	25.46	.66	.51	61.11	84.09	22.03	-0.87	0.39	63.35
Control	33	75.00	20.41	.66		64.00	79.55	19.90	-0.87		64.00
Total Test											
Treatment	33	80.11	15.67	0.38	.71	58.60	84.85	12.72	1.07	0.29	64.00
Control	33	81.41	11.45	0.38		64.00	87.75	8.70	1.07		56.55

The results of the posttests analysis suggest that the integration of an engineering project into a science unit of instruction had no statistically significant impact on student performance. These subsequent analyses extend the finding of no statistically significant difference to categories of test items. Although not statistically significant, the difference in gain between the treatment and control groups on reasoning questions was substantive. A larger sample size and/or analysis of covariance may have revealed statistical significance.

Integrated Instruction and Student Attitude/Interests

In addition to the quantitative analyses described above, qualitative analyses were used to answer the part of the first research question relating to the impact of engineering integration on student attitudes about and interests in science. An attitude/interest survey was administered to the participants in both the groups as part of Posttest 2. Responses from students in both groups were compared. The survey appears in Appendix C in its entirety, but each survey item is repeated below, accompanied by a discussion of the responses obtained from it.

With the goal of gaining insight into student attitudes and interests about science instruction, the qualitative data from the survey was analyzed in a four-step process (Creswell, 2008) as described in the Methods chapter. First, a “preliminary exploratory analysis” (p.250) was completed by reading through each question of the survey and making a separate list of varying responses or “text segments” (p. 251) received from students in both the treatment and control groups. Second, a frequency count was completed to identify similar or repeating responses for each question (see Appendix D). Third, the varying response lists and frequency counts for each question were compared to discover qualitative “themes” (p. 251) or similarities and differences in the attitudes and interests of the participants of the treatment and the control groups. Fourth, analysis continued by “layering the themes” and adding additional “rigor and insight" into the data collected (p. 259). Following this process, the quantity and quality of student responses for each group was compared.

Questions regarding the attitudes towards and interests in the Water Cycle Unit. The subsequent paragraphs will report the findings obtained from the first four survey questions relating to emerging themes.

How do you feel about the Water Cycle unit compared to other science units you have had? Responses from both the control and the treatment groups revealed a general positive attitude toward the Water Cycle unit with roughly the same number of positive expressions. Many students in both groups wrote such simple expressions such as, "I liked it because it was fun." All of the responses obtained from the control group, except one, were positive, but few showed comparisons of attitudes across units. For example, the response "I feel good" does not compare attitudes about the Water Cycle unit to attitudes about other units. In the treatment group all responses, but one, were positive and more responses contained comparison statements. To illustrate, one student wrote, "It was the best so far." Another student wrote, "I think this was the easiest unit we have had so far." A third student replied, "I have liked other science things better."

It is interesting that when asked a general *feeling* question, some students volunteered information about their opinions on the relative ease of the Water Cycle unit. Seven students in the treatment group expressed that the Water Cycle unit was "easier" than other science units. Only two students in the control group felt that the unit was easier. The fact that more students in the treatment group felt the unit was easier and that these students were volunteering this information in response to a general feeling question is significant in and of itself.

The treatment class responses included three references to the engineering integration. One student said, “I didn’t like it as much as engineering.” At first read this comment appears to suggest this child was thinking about science separately from engineering. Possibly this student only liked the engineering part of the unit and not the science part, but if that were the case, why would previous science experience be compared to engineering experience only? It would make more sense that this child would compare past science to current science/engineering considering the involvement in the science engineering integration. This child didn’t like “it,” (i.e., the other stand-alone science experiences) as much because they didn’t include engineering. We favor this interpretation because it is similar to the other two students who said “It was awesome because we got to test stuff,” and “It was better than the others because we were free on what to choose [for design/building materials].” These latter two responses reveal a sense of empowerment that may result from active nature of the engineering design cycle, i.e., planning designs, building and testing solutions, etc.

Write down anything that frustrated you during the Water Cycle unit. During the think aloud validation, students interpreted the word “frustrated” as referring to something that they didn’t like or bothered them for some reason. For example, frustration could come from an inability to spell a word, the challenge of distinguishing among similar-sounding vocabulary terms, or that a concept was hard to understand. Students also may have identified “frustration” as an opposite emotion compared to “enjoyment” which is asked about in question four of the survey. When students were asked how much they “enjoyed” the water cycle, some chose to report on the feeling of boredom. Additionally, frustration could have been interpreted as boredom in terms of lack of interest possibly because the topic was not challenging enough, personally interesting, or excessively difficult to understand. This issue will also be discussed further in the respective section regarding question four of the survey.

In response to this question, the majority of students in both groups expressed that "nothing" frustrated them. Based on the above meanings of the word "frustrated," this means that nothing within the unit bothered them or that they enjoyed everything. Within each group, however, there were six students that named a specific science concept that frustrated them (e.g., "condensation") or that they were frustrated by the "big words." This frustration came from a concept being hard to read or understand. This type of frustration is not unique to science or engineering. One student in each group expressed frustration with the end-of-unit test. One student in the treatment group and two students in the control group appear to be thinking about boredom in terms of not being challenged enough while learning a topic. Two students said that the unit was "too easy," while another replied, "I already knew everything."

Differences in the nature of frustration between the control and the treatment groups were found. In the control group students expressed being frustrated with learning about the temperature needed for water to change state. They could have been frustrated in terms of boredom with the concept because it was not challenging or bothered because the concept was hard to remember or understand. No students in the treatment class expressed this frustration. Six students in the treatment group expressed frustration with aspects of the engineering design project such as "my engineering team." This response is interesting considering the student was probably bothered by the nature of group work and the challenges that lie therein. This frustration is not necessarily solely caused by the engineering itself, but by the difficulty in learning to cooperate and collaborate with others. This frustration could have occurred within a science experience versus an integrated science/engineering experience. The other two students reported frustration that came from “the order to build things in” and “people knocking over our water filter project.” These comments stem from challenges encompassed by participation in the engineering design cycle. Students are allowed more autonomy in design in terms of planning and building. Along with this autonomy comes the risk of other students not taking responsibly or care to consider the work of other students.

What was the most interesting part of learning about the water cycle for you? When asked about the most interesting part of the Water Cycle unit, students responded in three different ways. The first kind of response shown by students was general and positive. Eight students from each group responded this way, with many students writing “I liked everything.” The second kind of response identified in both groups included naming or referring to a specific science concept learned. Twenty-three participants in the control group gave either one word responses such as “condensation” or very general responses such as “how water evaporates.” Thirteen students in the treatment group responded with a reference to a science concept and elaborated on the concept with more than just one word. For example, one student wrote “I enjoyed learning how water gets around” and another replied, “It is interesting how the sun does all the work.” A third student replied, “I liked learning about the kinds of precipitation that we have and every other thing about precipitation.” When comparing the two groups it is curious that more students in the control group referenced a science topic learned, but the students in the treatment group used slightly more specific and developed sentences.

A third way students responded to this question was only found among responses from the treatment group. Eleven students in this group referenced the engineering project as the most interesting part. One student wrote “I liked using the engineering designs with the water cycle.” Another wrote, “We BUILT the water cycle.” A third student explained that the most interesting part was “Learning how other engineering models used all their materials.” And finally, a fourth student replied that the most interesting part was “watching it take place in our engineering designs.” It appears that these students, as well as the others, acknowledged that engineering enhanced their science-learning experience. This is significant because students not only recognized how the instruction was different, but also expressed interest in and positive attitudes from participating in the integration.

How much did you enjoy learning about the water cycle? Why? Positive and negative attitudes about the science unit were shown by participants in both groups. One student in the treatment group and four students in the control group expressed being “bored.” The issue of interpreting the word “boredom” as addressed above applies here, as it did in question two. Some students may have expressed boredom because of lack of interest in the content being addressed, while others may have felt bored because they did not view the content as challenging. It is interesting to note that the student in the treatment group whom expressed frustration with the unit being too easy in question number two, similarly expressed this opinion in response to question four. In the control group different students expressed boredom in question two than those who expressed lack of enjoyment in question four.

More students in the control group had general non-scientific responses such as “I liked it because it was fun,” while students in the treatment group gave specific responses containing learned science vocabulary. *Percolation, groundwater, evaporation*, and *states of water*, were among the specific vocabulary terms and phrases used by the treatment group. Once again these responses revealed that students in the control group were inclined to respond in an agreeable or complacent way, while students in the treatment group appear empowered by their ability to understand and apply science knowledge.

Some students in the treatment group referenced enjoying participation in the engineering design cycle. One student wrote, “Because I like knowing how stuff works, that’s why I’m going to be an engineer.” This statement is very enlightening, because this student was able to project a future identity based on the integration experience. There may have been other experiences in this child’s life that might support the creation of the identity to “be an engineer,” but the student chose to mention this in response to the survey question which seems to suggest that the integration was meaningful as well as enjoyable. It may be important to also consider that students may have been able to see themselves as a future scientist based on experiences from the unit, but no other students chose to describe this feeling or perception.

Question regarding application of science content knowledge. The subsequent paragraphs will report the findings obtained from survey question five.

If you were stranded on an island and only had the salty ocean water to drink, how would you get fresh water? Students in both groups proposed similar one-step solutions: (a) “boil water,” (b) “use a filter,” (c) “dig a hole,” or (d) “wait for precipitation.” Complacent, or passive, responses, such as “use my phone to call my dad” or “I don’t know” were also given by students in both groups, but were more common among control group students. The control group had more students suggest “to wait for precipitation” to occur or to go ahead and “drink the salt water” than the treatment group did. The control group also had four students suggest looking inside trees, plants or fruit for freshwater, while the treatment group had no responses with that suggestion. Control group responses could suggest that some did not fully grasp the science content, i.e., understanding differences between salt water and freshwater, a factor underlying their complacency.

More students in the treatment group responded with an idea that involved creating or designing something than those in control group. These statements contained multi-step solutions such as “dig a hole, then put salt water in it, cover it with something, then wait for it to evaporate and collect on the cover.” Only one student in the control group suggested creating or building something and the majority of solutions given by the control group involved only one step— “find some fruit,” “boil it,” or “swim away.” These responses from the treatment group seem to reveal a sense of empowerment once again. The engineering experience to designing, building, and testing was unique to the treatment group and may have given students a sense of control and a desire to engineer a solution. On the other hand, responses obtained from the control group continued to reveal complacency and passivity. The multiple-step solutions provided by the treatment group also seems to suggest that students in this group were more inclined to think with cognitive complexity. They seemed unafraid to think deeply about a problem and come up with a solution.

More students in the treatment group referred to using processes of evaporation and condensation to help clean the water. These students showed a greater understanding of science content learned and an enhanced ability to apply that content to a specific situation.

In summary, the results from the qualitative data suggest that the overall positive attitude toward science was similar for both groups. Similar science concepts interested students in both groups as well as caused frustration. Differences between the groups were discovered not only in quantity, but also in quality of responses. The control group revealed responses that were more simple or general, tended to be more agreeable, and even sometimes complacent. The treatment group contained responses that were slightly more cognitively complex, showed a sense of empowerment, revealed application of scientific understanding and the ability to engineer a solution to a problem. In addition, the treatment group also revealed energized interests and attitudes towards engineering. Some students expressed frustration with certain aspects of the engineering design cycle and others expressed enjoyment in the opportunity for autonomy. The nature of these differences between groups is surprising in light of the lack of difference between groups on the posttests measures which contained items reflecting higher level thinking. When placed in a situation in which students were asked to display their scientific knowledge on the posttests, the treatment group did not *display* a deeper level of science understanding. However, when placed in a situation in which they were invited to *apply* that knowledge, the treatment group clearly displayed deeper understanding.

Chapter 5

Discussion

The purpose of this study was to examine the effects of integrating science and engineering content and pedagogy on student learning at varying cognitive levels. An additional purpose was to examine how integration may affect student attitudes and interests in science. The following chapter is a discussion of the conclusions and implications of the results of this research and recommendations for further research.

Conclusions

The findings from this study contribute to the body of educational literature addressing key factors and issues relating to improving STEM education. As discussed in the literature, a current reform movement focuses on improving education within the STEM disciplines—science, technology, engineering, and math. One goal of this movement is to generate students who have the skills and abilities to solve future problems and could engage in future STEM careers. Researchers (Gallant, 2011; Laboy-Rush, 2011; Sanders, 2009) suggest that implementing STEM integration within levels of K-12 education may be key to improving the state of STEM education and reaching the goal of filling future STEM careers.

Through an integrated science-engineering unit of instruction, this study has allowed me as an educator to realize that including engineering content and pedagogy within science instruction is a critical part of improving STEM education, despite the initial comparisons between the achievement of students in the control and treatment groups revealed. These results alone suggest that the science-engineering integration did not increase student learning in science. Although no statistically significant difference suggests that science learning was not increased, it is important to recognize that the treatment group gained knowledge of engineering content and pedagogy that otherwise would not have occurred. These results concur with the research done by the Boston Museum of Science as they assessed student conceptions of engineering and found that conceptions changed significantly after students participated in an *EiE* unit of instruction (Lachapelle and Cunningham, 2007). Additionally, responses obtained from the survey provide some evidence that there was greater science learning among students in the integrated science-engineering group, as described below.

Increasing student enjoyment and interest levels in STEM disciplines is another key aspect of improving STEM education. Researchers of STEM integration studies, especially those from the Boston Museum of Science, address this issue and report on student motivation, attitudes, perceptions, and interests in STEM disciplines (Burghardt & Knowles, 2006; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Jocz & Lachapelle, 2012; Knight & Cunningham, 2004; Satchwell & Loepp, 2002). Although discussed in chapter four to some degree, a summary of the responses obtained from the attitude/interest survey will provide additional insights regarding the effects of integrating science and engineering pedagogy and content on student learning and on student attitudes and interests in science. When asked to compare their experience in the Water Cycle unit with their experience in other science units, students in the integrated science-engineering group were more articulate in their responses, were more inclined to express the notion that the science was “easier” to learn, and evidenced a greater sense of empowerment. Students in both groups expressed similar levels of frustration but were frustrated by different issues. Students in the science-only group seemed more frustrated by the science content, whereas those in the integrated science-engineering group were more frustrated by aspects of engineering design constraints as well as aspects of participation in a collaborative engineering design challenge, i.e., disagreeing with partners and others interfering with their design. The engineering opportunity, although frustrating to some, may have allowed for greater levels of reasoning to occur. According to educational psychologist Jean Piaget, frustration is an important part of the reasoning process. Opportunities that create cognitive disequilibrium yield the construction of new understandings and development. In expressing their levels of interest, students in the integrated science-engineering group expressed more elaborate responses and many were quite adept in expressing a recognition of the effects of engineering experiences on their science learning. This shows a high level of metacognition. When asked about their levels of enjoyment, responses from students in the integrated science-engineering group were more scientific and often explicitly mentioned engineering. Finally, when invited to apply their science knowledge in a "real-life" scenario, students in the integrated science-engineering group responded in a more active and creative manner than students in the science-only group. Their responses were more intricate and incorporated more science. Therefore, as seen from the summarized survey results, it can be concluded that the integration of science and engineering pedagogy and content did have an effect on student learning, as well as student attitudes and interest in science. These findings add to the educational literature available within STEM education and coincide with the similar positive outcomes in student conceptions, interests, and learning found in studies investing the effects of the EiE curriculum (Faux, 2006; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Lachapelle & Cunningham, 2007; Lachapelle, Cunningham, Oware, & Battu, 2008).

Implications

The findings from this study suggest that integrated science and engineering instruction may help to improve students' overall ability to deeply understand and apply science content. In addition, the results suggest that students' participation in the integration may have had a positive influence of their attitudes toward and interests in science and engineering.

If our goal, as a nation, is to improve STEM education and prepare students for careers within STEM disciplines, then it is necessary for teachers to understand how to engage students in positive, authentic, integrated STEM learning situations that powerfully influence attitudes and interests while also allowing for meaningful, deep understanding and application of content. It is also necessary for curriculum developers and researchers to study and develop instructional models that will effectively allow teachers to facilitate such learning experiences. The knowledge gained by myself, as the researcher, while attempting to design and implement an integration model for teaching integrated content and pedagogy is valuable. Since the first attempt at such a task yielded immense learning, it would follow that future attempts would produce greater opportunities for me, as a teacher and a researcher, to adjust and improve instruction for my students. More needs to be done to find successful models for planning and implementing integration which will allow teacher education in this area to increase.

Recommendations for Future Research

The results of this study suggest that an integrated unit of instruction may help improve student learning in science as well as support positive interests in and attitudes towards science. Further research, including that which integrates other content areas within STEM disciplines at the elementary level is suggested.

In addition, this research suggests that other questions and ideas for further STEM integration research will emerge as more elementary teachers engage in this practice. For example, a teacher might wonder about the level of constraint that should be allowed as students participate in scientific inquiry integrated with the engineering design cycle. Should students be limited in supplies they are allowed to use? Does having less constraints lead to more room for student misconceptions? These issues could affect student learning as well as student attitudes. Future research could rely on more kinds of qualitative data sources collecting information on student perceptions of their own learning. Do students view themselves differently when they participate in integrative experiences? A study where students keep a reflective journal through the integration process might yield some fascinating insights on student perceptions. This could be helpful in terms of considering the future career positions within STEM and if students view themselves as someone who might follow that career path following participation in an integrated curriculum experience, particularly one involving engineering**.**

Another possibility for future research may be to help teachers learn to design integrated models of instruction. This process could be a form of professional development used to help teachers develop skills and beliefs needed to successfully implement STEM integration in the K-12 classrooms. Researchers could study teacher thinking throughout the process of planning and implementing an integrated unit of instruction. If a reflective journal was kept by the teacher insights gained would add to the literature towards developing an integrated learning model of instruction that could possibly lead to future teacher development.

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Appendix A

Posttest 1

Name: ______________

Utah Environments

Write the correct environment next to the description. Each environment may be used more than once.

desert, wetland, forest

______________ 1. slow moving streams, frogs, deciduous plants, muskrats, carp, catfish, cattails
_______________2. sagebrush, ravens, jackrabbits, prickly pear cactus, lizards
_______________3. high elevation, high precipitation
_______________4. little rain, low elevation
_______________5. consists of soil, water, and plants and can be found at any elevation

Multiple Choice: Circle the best answer for each question.

6. Which plant would most likely be found in a desert area of Utah?

a. cottonwood tree
b. cactus
c. cattail
d. blue spruce

7. Consider the following animals, elk, moose, foxes, rabbits. Which are they?

a. vertebrates
b. invertebrates
c. amphibians
d. reptiles

8. Tyler is looking for information about the animals found in a forest. Which book would help him the most?

A. <u>Amazing Animal Antics</u>
B. <u>Animal Babies</u>
C. <u>Endangered Animals</u>
D. <u>Mountain Animals</u>

9. Use this information on a location in Utah to answer the question.

Temperature Range	Elevation	Rainfall
68-96 F	3,000 to 4,500 feet	Below 5 “

Which animal might be found living here?

A. tortoise
B. seagull
C. moose
D. bear

10. Use the key below to answer the question.

1a. more than 4 legs	go to 2
1b. 4 or fewer legs	go to 5
2a. 6 legs, 3 main body parts	go to 3
2b. more than 6 legs	go to 4
3a. clear wings, have a stinger	Animal A
3b. colorful wings, long mouthpart for sucking nectar	Animal B
4a. 8 legs, 2 main body	Animal C
4b. more than 8 legs	Animal D
5a. no wings	go to 6
5b. two wings, feathers	Animal E
6a. skin with fur	Animal F
6b. skin with out fur	go to 7
7a. smooth, wet skin without scales	Animal G
7b. dry, scaly skin	go to 8
8a. 4 legs	go to 9
8b. no legs	Animal H
9a. protective shell on back	Animal I
9b. no protective shell on back	Animal J

What is the animal of the letter?

A. Animal G
B. Animal H
C. Animal I
D. Animal J

11. A hummingbird is a tiny bird with a very distinct looking beak. How does this beak help the hummingbird to survive?

A. it is used to spear fish
B. it helps to suck the nectar from flowers
C. it is good for scooping up seeds
D. it is used to build nests

12. What would have to change for moose to live successfully in the desert?

A. Moose would have to lose their large horns.
B. Moose would have to learn to run faster in sand.
C. Deserts would have to grow more vegetation that moose eat.
D. Deserts would have to exist at a higher elevation.

13. What is the difference between Utah forests and wetlands?
A. Utah forests usually have more different kinds of trees and shrubs
B. Forests have more animals and birds than wetlands.
C. Utah forests have rivers but do not have cactus, lizards, or rattle snakes.
D. Both forests and wetlands have water, but only wetlands have fish and birds.

14. Many animals have specific behaviors to help them survive. Which of the following words means to move from one place to another when the seasons change?

A. hibernation
B. regurgitation
C. migration
D. elevation

15. What do trout mostly eat?
A. insects
B. other fish
C. spiders
D. weed seeds

16. If Utah were left in its natural state, which environment would it mostly be?
A. forest
B. ocean
C. wetland
D. desert

Write an answer to each question. Please use complete sentences.

17. In September, Katie goes for a drive up Hobble creek Canyon. She sees that the leaves on all the trees are yellow and brown. What kind of trees could she be looking at? Are they coniferous or deciduous trees? Explain your thinking.

18. You go to Utah lake on a bright sunny day. Describe the interaction that takes places between algae, brine shrimp, and seagulls.

19. How does a reptile's skin help them live in desert environments? Give specific examples.

20. Classify these animals based on their characteristics. Explain your thinking.

Appendix B

Posttest 2

Name: _________ **Water Cycle Test**

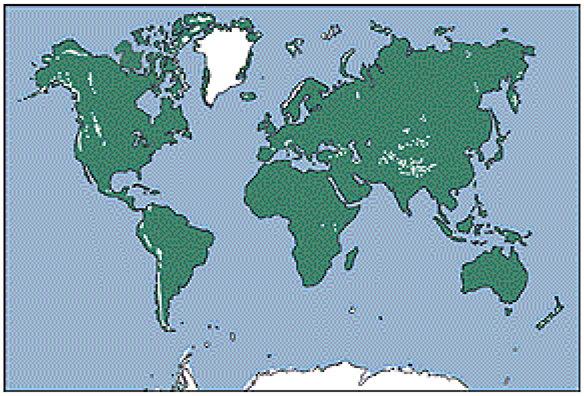
Write the correct process next to the description.

evaporation, condensation, precipitation

_________________1. Water collects on the side of a cold drink

_________________2. Snowflakes falling from the sky
_________________3. A puddle of water on the sidewalk disappears during the afternoon
_________________4. The grass is wet in the morning, but it did not rain during the night and the sprinklers were never turned on.
_________________5. Water changes to water vapor

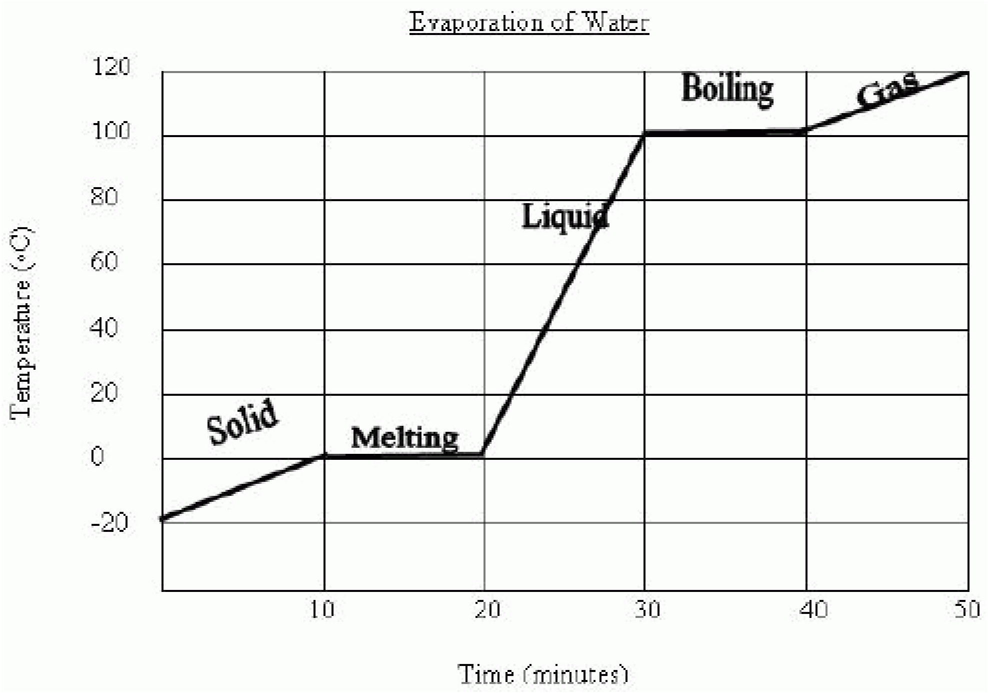
Choose the best answer for each question below.



6. Which statement can be made from looking at the map above.
A. Glaciers hold more water than oceans
B. Oceans have more freshwater than glaciers
C. Glaciers contain water in a solid state.
D. Glaciers store less water than oceans.

7. If you were looking for a supply of freshwater, which location would you go to?
A. The Pacific Ocean
B. Provo River
C. The Indian Ocean
D. The Atlantic Ocean

8. What does heat from the sun cause water to do?
A. travel deeper into soil
B. fall from clouds as rain
C. evaporate into the air
D. change into a solid



Use the chart above to answer questions 9 and 10

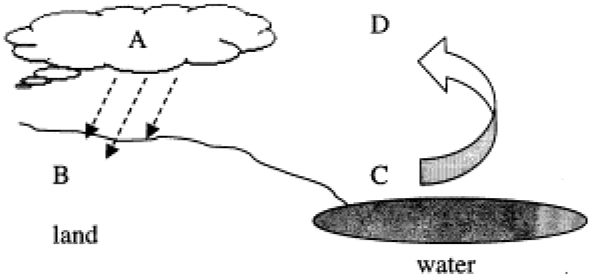
9. What happened to the water at 100 C?
A. The water began to turn to liquid.
B. The water began to condense.
C. The water began to turn from a liquid to a gas.
D. The water became a solid.

10. What happened between 10 and 20 minutes?
A. The ice was melting.
B. The ice stayed frozen.
C. The water was boiling.
D. The water was evaporating.

11. Which would be most helpful to farmers?
A. rainfall that evaporates quickly
B. rainfall that runs off the land quickly
C. rainfall that soaks into the soil slowly
D. very little rainfall

12. On what kind of day would you expect the most evaporation from the surface of a pond?
A. cold, rainy
B. cold, sunny
C. warm, rainy
D. warm, sunny

13. Where is most water found on Earth?
A. in glaciers
B. in lakes
C. in rivers
D. in oceans



Use the diagram above to answer questions 14 and 15.

14. Where is precipitation occurring?
A. from D to A
B. from A to B
C. from B to C
D. from C to D

15. Where is water evaporating into the air?
A. from D to A
B. from A to B
C. from B to C
D. from C to D

16. Which of the following is an example of condensation occurring in the water cycle?
A. water flowing down a river
B. underground water soaked into rocks
C. clouds or dew forming
D. ocean water changing to water vapor

17. Many Utah towns use water from wells for drinking. How does water get into those wells?
A. it has to be poured into them from water tanks
B. rain sinks down through the soil into them
C. it is pumped by large engines

D. it evaporates from the interior of the earth.

18. Which would complete the chart to the right?
A. snow
B. dew
C. frost
D. water vapor

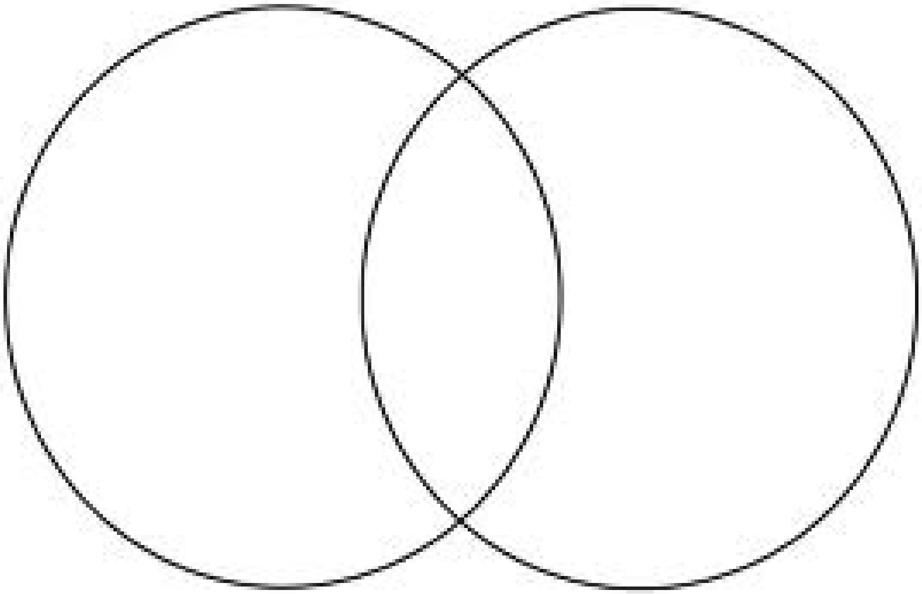
Examples of Precipitation

rain
hail
____

19. What does water vapor in the air return to Earth?
A. it evaporates and is blown by the wind
B. it evaporates and forms clouds
C. it condenses then precipitates as rain
D. it sticks to any surface it comes in contact with

Short Answer
Write an answer to each question.

20. 97% of the earth's water is found in oceans. 1% of the earth's water is freshwater. Use the Venn Diagram to compare and contrast ocean water with freshwater.



21. 2 % of the earth's water is stored in glaciers. In Alaska the Exit Glacier is melting. Why do you think this is happening? Make a prediction.

22. Look at the data in the table. What kind of precipitation would you expect of Friday? Justify your thinking.

Day	Temperature	Type of Precipitation
Sunday	30˚F	Snow
Monday	32 ˚F	Sleet
Tuesday	32˚F	Snow
Wednesday	40 ˚F	Rain
Thursday	29 ˚F	Snow
Friday	31 ˚F	Rain
Saturday	55 ˚F	

23. Look at the diagram of the campground. Identify as many different locations of water as you can. Make a list.

24. Davis City uses the river for all kinds of activities: washing laundry, fishing, dumping factory waste, and swimming. Evaluate this situation. Is it good or bad?

Appendix C

Attitude/Interest Survey

Name: ____________________

Attitude/Interest Survey

Write as much as you can about what you think or feel to answer each question.

1. How do you feel about the Water Cycle unit compared to other science units you have had?

2. Write down anything that frustrated you during the Water Cycle unit.

3. What was the most interesting part of learning about the water cycle for you?

4. How much did you enjoy learning about the water cycle? Why?

5. If you were stranded on an island and only had the salty ocean water to drink, how would you get fresh water?

Appendix D

Qualitative Data Analysis

Survey Response Frequency Counts

Question 1: How do you feel about the Water Cycle unit compared to other science units you have had?		
	Treatment	**Control**
I liked it/It was fun	6	12
Okay	3	4
The same	1	2
Bad	0	1
Liked other units better	4	1
It was harder	2	1
I feel good	3	9
Easier	7	2
More fun than other units	6	2
It was better	2	0
Question 2: Write down anything that frustrated you during the Water Cycle unit.		
	Treatment	**Control**
Nothing	18	23
Science concepts	5	4
Big words	2	1
Loved everything	1	0
The test	1	1
Too easy/knew everything	1	2
Temperatures	0	2
Question 3: What was the most interesting part of learning about the water cycle for you?		
	Treatment	**Control**
Percolation	5	8
Precipitation	2	2
Evaporation	5	8
Condensation	1	5
General "I like everything"	8	8
States of water	0	3
Engineering Projects	11	
Pollution	0	1
I don't know/nothing	1	

Question 4: How much did you enjoy learning about the water cycle? Why?		
	Treatment	**Control**
I liked it	11	8
It was fun/exciting	5	13
I don't care	5	2
I didn't like it/ It was hard	3	1
I was bored	1	4
Reference to engineering	5	
Use of science content vocabulary	8	4
Question 5: If you were stranded on an island and only had the salty ocean water to drink, how would you get fresh water?		
	Treatment	**Control**
Dig a hole	1	3
Try and engineer something	7	1
Use a filter	6	5
Boil the water	4	7
Use the processes of the water cycle	7	2
I don't know	4	2
Wait for precipitation	2	8
Call someone	2	
Wait to die	1	
Find another water source (stream, plants, fruit)	3	3
Drink the salt water	1	2
Swim away	0	2