Applying Curriculum Treatments to Improve STEM Attitudes and Promote STEM Career Interest in Fifth Graders

Bryanne M. Peterson

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Curriculum and Instruction

Jeremy V. Ernst, Chair
Bradley D. Bowen
Joseph S. Mukuni
Thomas O. Williams

February 7, 2018
Blacksburg, VA

Keywords: Elementary Education, STEM Education, Scientific Inquiry, Design Based Learning, Career & Technical Education, CTE, Career Interest, STEM Attitudes, Integrative STEM Education

Applying Curriculum Treatments to Improve STEM Attitudes and Promote STEM Career Interest in Fifth Graders

Bryanne M. Peterson

ABSTRACT

The Federal Government has called for an overhaul of STEM education, saying that we as a nation must increase "opportunities for young Americans to gain strong STEM skills" (Office of Science and Technology Policy, 2013, p.1). Economically, these skills expand beyond those that make good doctors, professors, and engineers; there is a world of jobs going unfilled because our students are graduating without the skills or knowledge that such opportunities exist. To increase the future STEM workforce, we first need to increase student awareness of a variety of STEM careers early on (Tai et al., 2006). Career decisions are being made by students as early as middle school (Tai et al., 2006); and very little if any STEM career exploration is occurring before high school. This lack of early exposure to STEM career options means that students are likely making decisions about career choices without accurate information; choosing a path before knowing about all the options. This research is broken into two manuscripts; the first of which examined the impacts of design-based learning and scientific inquiry curriculum treatments with embedded career content on the career interest of fifth-grade students as compared to traditional classroom methods. It found that there is an upward trend in career interest with the use of these curriculum treatments, but it is not a significant change, likely due to the short time period of the unit and/or small n. The second manuscript examined the effect of a design-based learning curriculum treatment implementation for a single unit on Radford City Schools fifth-grade students' STEM attitudes and interest in STEM careers through a pre/post design. The study showed statistically significant growth in overall STEM attitudes and within the science subtest specifically. Career interest in the general field of science showed a significant increase, while a change of interest in specific career areas was not statistically significant. Collectively, this research serves as a foundation for the effectiveness of having career awareness and career exposure opportunities built into active learning instruction, which does not occur currently. Built on secondary principles, but at a level appropriate for elementary students, using active learning opportunities with embedded career connections has the potential to be an effective solution to students' premature exclusion of STEM-related study and work options identified in the literature. Through preliminary exposure to this unique combination at the elementary level, a stronger foundation can be built for both ability and interest in STEM.

Keywords: Elementary Education, STEM Education, Scientific Inquiry, Design Based Learning, Career & Technical Education, CTE, Career Interest, STEM Attitudes, Integrative STEM Education

GENERAL AUDIENCE ABSTRACT

The Federal Government has called for an overhaul of STEM education, saying that we as a nation must increase "opportunities for young Americans to gain strong STEM skills" (Office of Science and Technology Policy, 2013, p.1). Economically, these skills expand beyond those that make good doctors, professors, and engineers; there is a world of jobs going unfilled because our students are graduating without the skills or knowledge that such opportunities exist. To increase the future STEM workforce, we first need to increase student awareness of a variety of STEM careers early on (Tai et al., 2006). Career decisions are being made by students as early as middle school (Tai et al., 2006); and very little if any STEM career exploration is occurring before high school. This lack of early exposure to STEM career options means that students are likely making decisions about career choices without accurate information; choosing a path before knowing about all the options. This research is broken into two manuscripts; the first of which examined the impacts of design-based learning and scientific inquiry curriculum treatments with embedded career content on the career interest of fifth-grade students as compared to traditional classroom methods. It found that there is an upward trend in career interest with the use of these curriculum treatments, but it is not a significant change, likely due to the short time period of the unit and/or small n. The second manuscript examined the effect of a design-based learning curriculum treatment implementation for a single unit on Radford City Schools fifth-grade students' STEM attitudes and interest in STEM careers through a pre/post design. The study showed statistically significant growth in overall STEM attitudes and within the science subtest specifically. Career interest in the general field of science showed a significant increase, while a change of interest in specific career areas was not statistically significant. Collectively, this research serves as a foundation for the effectiveness of having career awareness and career exposure opportunities built into active learning instruction, which does not occur currently. Built on secondary principles, but at a level appropriate for elementary students, using active learning opportunities with embedded career connections has the potential to be an effective solution to students' premature exclusion of STEM-related study and work options identified in the literature. Through preliminary exposure to this unique combination at the elementary level, a stronger foundation can be built for both ability and interest in STEM.

Keywords: Elementary Education, STEM Education, Scientific Inquiry, Design Based Learning, Career & Technical Education, CTE, Career Interest, STEM Attitudes, Integrative STEM Education

Acknowledgements

My journey at Virginia Tech would not have been possible without the enduring support of my husband, Easton. He supported me when I went for masters pregnant with our first child, and didn't divorce me when I brought up the idea of a doctorate after I had our second. For the past year, he carried the bulk of the family responsibilities, striving to give me the time I needed to reach my goals. From my three amazing children, I found inspiration, encouragement, and the desire to make them proud.

My doctorate is far from my own, as it took a team to make it a reality. Outside of my family unit, I especially need to thank my parents, Diane and Gregg, my second mom Karen, and Colleen (a better friend than I deserve) for taking on the parenting duties I could not while traveling to Blacksburg. I also need to thank my friend Kathryn, who took me in and made sure I took time for self-care (I remember- food is necessary). And finally, a thank you to my committee members, who guided me through this process and took the time to ensure the focus of this journey was learning, and not just ticking off the requirements.

Dedication

Taking on a doctoral program while rearing three young children is, perhaps, not an exercise in good judgment… but to my credit, it was only two when I started! Thankfully, through good judgment (and good fortune), I married Easton. And while he was the cornerstone of my support system, I have to dedicate this work to those that inspired me to go back to school again. And so, I dedicate this dissertation to our three ~~monsters~~ children- Cadence, Conor, and Carrigan. As I write this, I smile when thinking of each of you. I can only hope that my doctoral work didn't take me away from too many milestones or small moments, precious in their simplicity. I hope and trust that your educational journey will be improved through my efforts here, but more than anything, I hope that you can see that I'm working to make a difference in the world that will be yours one day. And so, this first big step is dedicated to you my loveys, I know it can't give us back the time we lost together, but hopefully it will inspire you to work to change the world one day, too.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

Overview

The need to prepare students in STEM fields has never been greater. In 2010, the U.S. Advisors on Science and Technology reported that "STEM education is essential to our economic competitiveness and our national, health, and environmental security" (2010, p. 2). Soon after, the Federal Government called for an overhaul of STEM education, saying that we as a nation must increase "opportunities for young Americans to gain strong STEM skills" (Office of Science and Technology Policy, 2013, p.1). STEM is an acronym for the overlapping fields of science, technology, engineering, and math; speaking broadly, scientific (and STEM) literacy is a necessity of future citizens, so that they can make informed decision-making in both personal and civic/cultural affairs (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 'Rising Above the Gathering Storm', 2010). Economically, these skills expand beyond those that make good doctors, professors, and engineers; there is a world of jobs going unfilled because our students are graduating without the skills or knowledge that such opportunities exist. STEM career fields are vast and varied, with opportunities at multiple levels of formal education; for instance, a two-year college degree can lead to a career in computer manufacturing as a technician.

Children are the future; one day, they will grow up and take jobs that support our society. But what happens if our children are incapable of doing the jobs society needs to be filled? What if our children, once all grown up, simply aren't interested in those jobs? Or worse, what if they have the skills, abilities, and general interest, but don't know the job even exists? These potential disconnects have the potential to derail the robust economy and National pride that comes with leading the world in innovation and technology in the modern age ('Rising Above the Gathering

Storm', 2007). Unfortunately, current research shows that the United States' future involvement in innovation and technology is at risk.

Academic Ability

Academically, American students are underperforming in science, technology, engineering, and math subjects (U.S Department of Education, 2015). Program for International Student Assessment (PISA) and Trends in International Math and Science Study (TIMSS) scores are consistently lower than other nations (Organization for Economic Co-operation and Development[OECD], 2016). The National Science Board reported that students in our educational system are failing, despite being in the most innovative, technologically capable economy in the world and that our decline of science and engineering workforce means a U.S. reliance on foreign-born scientists and engineers (National Science Board [NSB], 2010). Even twenty years ago, we as a field knew we were failing our students in math and science. As told by a Nobel Prize in physics winner and an associate director at the Teachers Academy for Mathematics and Science:

"The national picture of science education at the precollege level is a dismal one indeed, documented by countless commissions, panels, and national and state assessments. International tests...suggest that our students are inherently as bright as other students around the globe but that our schools are progressively, grade by grade, failing to educate them well in math and science" (Allen & Lederman, 1998, p. 158).

Allen and Lederman told the field American students were inherently bright but poorly educated. This should have been a call to action, a pivotal moment where the world, or at least our field, stood up and took notice, and made a change. But for all our progress, that sentence just as easily could have been uttered yesterday. "Grade by grade," we fail each year to provide our students with what they need to succeed at the next level. American students consistently underperform in science, technology, engineering, and math (STEM) subjects (U.S. Department of Education, 2015; National Assessment of Educational Progress[NAEP], 2015; OECD, 2016). According to the NAEP, 67 percent of eighth graders are not proficient in math (2015). Reality is bleaker when you unpack the data- a mere 16 percent of eighth-grade students eligible for the National School Lunch Program (NSLP) are proficient in math, with only 2 percent scoring advanced. Today's students are academically ill-prepared to take on the jobs of the future, especially those that are currently low SES.

Academic skills are not the only area of concern when it comes to preparing students for their future in society. Young people have an increasing disinterest in science and technology (Osborne & Dillon, 2008; Murphy & Beggs, 2005). This is problematic as it compounds the workforce problem; even if students are capable, if they are not interested, they are unlikely to pursue a career in a STEM field.

STEM Career Interest and Awareness

Interest in an academic area is important, but if it is not parlayed into an exploration of career options in that field, it is a lost opportunity. To increase the future STEM workforce, we first need to raise student awareness of a variety of STEM careers early on (Tai, Liu, Maltese, & Fan, 2006). Career decisions are being made by students as early as middle school (Tai et al., 2006); and very little if any STEM career exploration is occurring before high school. This lack of early exposure to STEM career options means that students are likely making decisions about career choices without accurate information; choosing a path before knowing about all the possibilities. We need to increase awareness of STEM career options before students reach middle school to ensure we are not losing members of the future stem workforce due to simply not knowing a career exists.

Three identified general issues are at play when it comes to building the STEM workforce of tomorrow: academic ability, STEM interest, and STEM career awareness. The identification of these mechanisms aids in the search for potential solutions to the STEM workforce crisis that is on our nation's horizon. This study explores facets of STEM Interest and career awareness and examines whether the implementation of an active learning strategy, specifically design based learning or scientific inquiry, support an increase in STEM career interest and students' confidence and efficacy in STEM subjects (STEM attitudes).

Rationale for the Study

As a field, we know that lower socioeconomic status (SES) students are less likely to attend college and that a lack of higher education severely hinders the income-producing potential across an individual's lifespan. Students from low social economic status (SES) groups remain underrepresented in higher education and particularly in STEM fields. This is particularly true for Appalachian youth; finding ways to increase their representation is an important step for both the region and diversity efforts of the nation-at-large.

General research on underrepresented groups is not necessarily transferable to Appalachia (Irvin, Byun, Meece, Farmer, & Hutchins, 2012). So, the addition of research specific to rural Appalachia and STEM attitudes and STEM career interest improves our ability to design and advocate for interventions that will help students in this area be better prepared for a brighter future.

Current Research

Current research on workforce development models shows that over "the past decade or so, numerous reports have reflected concern among policymakers, practitioners, and researchers that the USA is falling short in producing a next generation of science, technology, engineering, and math (STEM) talent to replace those who will soon retire" (as cited in Reider, Knestis, & Malyn-Smith, 2016, p. 847). This study will show how the use of scientific inquiry and design-based learning as curriculum treatments at the fifth-grade level affects students' confidence and efficacy in STEM subjects (STEM attitudes) and their interest in STEM careers. Gains in each of these areas have tremendous potential value to stakeholders in the educational system. In addition to contributing these measurable outcomes, this study can serve as a conversation starter for the benefits of adapting career and technical education (CTE) to the elementary level. CTE programs prepare students for college and careers; within CTE applied technical learning is integrated with rigorous academics for students to develop the skills needed for success (ACTE, n.d.). An early foundation of STEM and CTE is beneficial to all stakeholders (students, parents, teachers, school administrators, employers, and policymakers) alike.

Elementary students are not usually considered when discussing CTE. This is a mistake, as elementary school serves as a natural foundation for career awareness and skill building (e.g., foundational workplace readiness skills). Children's attitudes and beliefs formed during this period, along with their experiences at this age, create a foundation for later vocational development (Hartung Porfeli, & Vondracek, 2005; Watson & McMahon, 2005). Intentionally introducing CTE at the elementary level provides two major benefits; first, it offers the opportunity to set a foundation of skills necessary for success in secondary CTE programs, as well working toward college and career readiness. Second, it offers the opportunity to expand students' career awareness when their minds are still open to all possibilities; research at the elementary school level indicates that some students begin to limit their career goals as early as elementary school and that students have inaccurate views of job availability that continues through grade 12 (Helwig, 1998; Auger, Blackhurst, & Wahl, 2005; Walls, 2000). This study offers an opportunity to share this knowledge with teachers, school administration, parents, students, and even policymakers; it can serve as a spark to expand CTE into the elementary classroom.

Early STEM efficacy and career interest can keep the STEM workforce pipeline from narrowing unnecessarily, providing a broader potential homegrown STEM workforce. This is important for multiple levels of stakeholders. Employers will see an influx in potential employees, which means a higher quality of employee to fill strategic jobs in organizations that require US citizenship, such as secure national laboratories and defense agencies, (Casey, 2012). Which, in turn, benefits government policymakers. At a more micro level, the students and their families can benefit from early and continued STEM efficacy and career interest because STEM fields offer higher income and financial security, even in jobs that do not require baccalaureate degrees (Rothwell, 2013).

Stakeholders

The economy and society-at-large benefit from students having a strong foundation in STEM. As Rothwell noted, macroeconomics research has found great economic growth from education (Glaeser, 2009); as Glaeser puts it, "educational investment is extremely persistent." Knowing that educational investment is key to society's continued economic success, and knowing that the global economy is increasingly STEM focused, stakeholders need proven methods to increase STEM competency and interests in the future workforce, studies like this one can provide that.

One of the four core principles spelled out by the U S. Department of Education (2012) is the necessity for stronger collaboration between all stakeholders in education. The data and outcomes of this study will be shared with key stakeholders; this is important as the more informed a stakeholder is, the better prepared they are to make decisions that can improve and transform student success. Armed with the knowledge of how to make a difference in their classes, elementary teachers can opt to try these methodologies in their classrooms, and seek out PD that supports CTE integration at the elementary level. Secondary CTE teachers benefit from this increased use because students will come to them with existing workplace readiness skills, allowing the teacher to advance them further in less time, which makes the student more marketable to employers. CTE teachers can also affect change by collaborating with elementary teachers; this would be more likely to occur since they would have research showing that their efforts make a difference.

When the school administration has access to outcomes such as this, change can begin on a larger scale, because they control funding. The recent enactment of the Every Student Succeeds Act (ESSA) marked a major step toward ensuring students graduate from high school college and career ready, and it also distributed funding responsibilities down to state and local administrators. ESSA already “includes critical measures to strengthen the role of CTE in our nation’s K-12 education system by promoting activities that integrate academic and CTE content in the classroom, expanding college and career guidance programs, improving the availability of CTE student performance information and recognizing CTE as a core component of a well-rounded education” (Coppes, 2016). Administrators can use outcomes from studies like this one to support sending CTE funding to the elementary level, where it has not traditionally been funneled. The most significant source of CTE funds for the past 23 years being the Perkins Act, which is identified for secondary and post-secondary use.

As noted above, administrators have the ability to induce change on a larger scale, but this isn't exclusive to funding access. The models and issues discussed in this study (and others like it) have implications for the design, development, and evaluation of K-12 STEM workforce education programs. With access to this information, administrators could ensure that when setting conditions for student learning, career awareness and early workplace readiness skills are considered for elementary curriculum. They can alter existing PD to encourage and support strategies that develop students career awareness and early workplace readiness skills at the elementary level. By emphasizing and prioritizing programs like this, the administration becomes a change agent itself. Individual administrators can affect change in both directions, influencing teachers and policymakers.

Policymakers control funding; to affect change on a national, or even state, level, they must see the value of investing in elementary CTE initiatives. As Betsy Brand and her colleagues point out, "Research and data on outcomes of CTE students have been key in convincing policymakers of the value of CTE. As outmoded ideas of technical and manufacturing jobs are slowly being replaced with an understanding of the value of today's highly skilled technical careers, CTE is becoming an educational pathway of choice" (Brand, Valent, & Browning, 2013, p. 7). The last decade has seen great strides in the validation of CTE as critical for public education, with research like this study, we can show policymakers that incorporating CTE principals early has long-term benefits for both students and society. By investing funds into CTE earlier, at the elementary level, students will be able to reach higher, and employers will gain a more qualified workforce. Both policymakers and employers need to be shown that we must play a long-game, planning ahead 10 and 20 years, instead of the current model which is looking only four to eight years.

Purpose of the Study

Early development of students' foundational STEM knowledge and abilities have been largely ignored at the elementary level (DeJarnette, 2012). The purpose of this study is to investigate the effect of utilizing scientific inquiry and design-based learning treatments at the fifth-grade level has on students' confidence and efficacy in STEM subjects (STEM attitudes) and their interest in STEM careers. By examining the impact of active learning curriculum interventions, this research will add to the body of knowledge related to STEM instruction and also to the incorporation of CTE principles in the elementary grades. The findings from this research study provide educational leaders and practitioners insight on how best to improve student outcomes for both short-term and long-term objectives that can benefit both the student and the region.

Definitions of Terms

The following definitions, are provided to orient the reader to key terminology in this research.

Active learning (alternative) instruction. Active learning is generally defined "as any instructional method that engages students in the learning process"; it is a broad category of instructional methods that serve as an alternative to a teacher-centered, direct instruction model (Prince, 2004). Active learning instruction requires active student participation in classroom activities (Prince, 2004). Active learning is not an instructional method, but rather an approach to increase student engagement (Prince, 2004; Gleason, et al., 2011) "Active learning can involve adding small, intermittent activities to existing courses or can require a complete restructuring of an entire course by using a distinct active-learning approach. No single approach is exclusively better than any other, and some strategies may work better with certain teacher personalities and teaching styles" (Gleason, et al., 2011). There is a long and varied list of strategies which fall under the umbrella of active learning, to include: peer teaching, cooperative learning groups, case studies, simulations, games, Think-Pair-Share, Minute Writes, Muddiest Point, notes exchange, Socratic Questioning, debates, fishbowl, role plays, student presentations, use of polling devices, case studies, online supplementation, Problem-based learning, Project-based learning, Design-Based Learning, and many of others, as well.

Design-based learning. Design-based learning (DBL) is a teaching method that provides a natural and meaningful venue for learning both science and design skills through design projects (Kolodner, 2002). DBL "enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles, and various skills" (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008). It is an active learning process and as such, a teacher's role is no longer that of lecturer, instead his roles become that of tutor, guide, and partner in the learning process (Prince, 2004). DBL is typically team-based, and therefore collaborative in nature; students that engage in cooperative learning gain success in academic and non-academic achievements (Lazarowitz, Hertz-Lazarowitz & Baird, 1994; Verner & Hershko, 2003), and show gains in their interpersonal communication skills, presentation skills, and problem-solving skills (Butcher, Stefanai & Tariq, 1995; Doppelt, 2004; Doppelt, 2006). Students are motivated to learn using DBL strategies because of the more explicit connection between their knowledge and real-life situations thanks to the design's purpose of meeting current and real needs (Doppelt, 2002; Hill & Smith, 1998).

Inquiry-based learning. In scripted inquiry, teachers are at the center- they set the goal, ask the questions, provide the materials and procedures, and then discuss the "correct" results and the "correct" conclusion (Bonnstetter, 1998). In contrast, inquiry-based learning ''provides a richer, more scientifically grounded experience than the conventional focus on textbooks or laboratory demonstrations" (Bransford, Brown, & Cocking, 1999, p. 172). It is a process of discovering new causal relations, "with the learner formulating hypotheses and then testing them by conducting experiments and/or making observations...the main aim of inquiry learning to be the improvement of transferable skills needed for making discoveries rather than simply discovering new relationships: (Pedaste, Mäeots, Leijen, & Sarapuu, 2012, p. 82). This process often involves the application of several problem-solving skills and is viewed as an approach to solving problems (Pedaste & Sarapuu, 2006); students do this by carrying out a self-directed, partly inductive and partly deductive learning process through investigative experiments that include at least one set of dependent and independent variables (Wilhelm & Beishuizen, 2003). As an an educational strategy, in inquiry learning, students construct knowledge by utilizing methods and practices similar to those of professional scientists in order to construct knowledge (Keselman, 2003) and emphasizes the learner's responsibility for discovering knowledge that is new to the learner and active participation and (de Jong & van Joolingen, 1998).

Scientific inquiry. Scientific inquiry is "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NRC, 1996, p. 23). We know that purely exploratory inquiry with minimal guidance from teachers does not lead to learning (Kirschner, Sweller, & Clark, 2006), so scientific inquiry provides a structure and purpose. In the classroom, scientific inquiry-based student work resembles that of practicing scientists, and teachers serving as guides “ready to respond to the student questions as they emerge from their investigations” (Grigg, Kelly, Gamoran, & Borman, 2013, p.40). Students conduct investigations to test questions about the natural world and then use the evidence they collect during their investigations to articulate an explanation in terms of scientific concepts and principles (Grigg, et al., 2013). According to the Framework for K-12 Science Education, “scientific inquiry embodies a set of values. These values include respect for the importance of logical thinking, precision, open-mindedness, objectivity, skepticism, and a requirement for transparent research procedures and honest reporting of findings” (NRC, 2012, p.248).

Signature pedagogy. A signature pedagogy is “a systematic, shared set of practices that distinguishes the preparation programs in a given profession” (Viadero, 2005, p. 1). Signature pedagogies “form habits of the mind, habits of the heart, and habits of the hand” (Shulman, 2005, p. 59). There are three characteristics of a signature pedagogy of a profession (Shulman, 2005). First that the pedagogy is pervasive and routine; it cuts across institutions, programs, and courses. Second, public student performance is always part of the curriculum; this ensures students are active and interactive learners. Finally, it acknowledges that emotional investment it necessary for intellectual growth and professional formation, and as such a signature pedagogy involves risk-taking and managing uncertain situations (Shulman, 2005).

Traditional assessment. Traditional assessments (TAs) have a standard delivery and response format, of typically single-answer questions, comprised mainly of multiple choice;

matching; or true/false; taken in a paper-and-pencil format to provide a simple and quick method of learning about students' knowledge of a subject (Wiggins, 1990; Oberg, 2010). TAs tend to reveal only the lowest levels on Bloom's taxonomy (Krathwohl, 2002; Krajcik, Blumenfeld, Marx, & Soloway, 1998), "whether the student can recognize, recall, or 'plug in' what was learned out of context" (Wiggins, 1990, p. 1). They rely "on 'indirect or proxy 'items' -- efficient substitutes from which we think valid inferences can be made about" (Wiggins, 1990, p. 1).

However, there are obvious benefits to TAs; they are easier to create and quick to administer to large groups of students and score (Oberg, 2010). In this manner, TAs offer important, but limited, information for educators (Oberg, 2010). On their own, TAs may be inappropriate for certain teaching methods, such as project-based learning (Krajcik, et al., 1998) and/or certain learners, such as students with some disabilities or from non-dominant cultures and language groups. They can also be ineffective because the test's presentation is different from class experience, or it could have content unrelated to previous knowledge- and in either case this can directly impact the student's ability to show their mastery (Estrin, 2002). Instead, teachers need to expand the repertoire of assessment strategies to create a balance between traditional and alternative assessments (Stanford & Reeves, 2005).

Traditional Instruction. "A traditional curriculum is simple with knowledge being directly transmitted to students, whereas an integrated curriculum is complex in many ways" (Zhbanova, Rule, Montgomery, & Nielsen, 2010). Traditional instruction is based around a teacher-centered, direct instruction approach where the teacher undertakes the task of transferring knowledge to the student (Zhbanova, et al., 2010; Chang & Mao, 1999). Students "follow directions, recall previous knowledge, and work individually" (Zhbanova, et al., 2010), passively receiving information from the teacher (Prince, 2004). Traditional instruction includes the use of textbooks, occasional demonstrations and a review of textbook topics (Chang & Mao, 1999). This method requires less student participation and requires a larger focus on classroom management from the teacher (Zhbanova, et al., 2010).

Project-based learning. Project-based learning is a comprehensive approach to classroom teaching and learning designed to engage students in investigation of real-life problems through the design of their own artifacts (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998; Schneider, Krajcik, Marx, & Soloway, 2002; Solomon, 2003). In PBL, "the doing and the learning are inextricable" as the process of artifact creation is the act of constructing the knowledge (Blumenfeld, et al., 1991, p. 372). PBL is student-centered; it allows students to learn and to solve problems, while teachers design the curriculum then play the roles of helpers, process evaluators, and co-learners (Lou, Liu, Shih, & Tseng, 2011).

Rooted in constructivism (Krajcik & Blumenfeld, 2005; Lou, et al., 2011), the principal values in PBL are "constructing knowledge through trial and error," "learning by doing," and "applying new knowledge to new circumstances" (Colley, 2008; Singer, Marx, Krajcik, & Clay-Chambers, 2000; von Glasersfeld, 1995; Lou, et al., 2011). According to Lou et al., from the student perspective, PBL characteristics include: being learning centered; encouraging cooperative learning; allowing students to continuously improve work or outcomes; active discover knowledge; produce artifacts; and depends on high-level skills (2011). At the classroom level, PBL is focused on: a driving question built around a problem to be solved; immersion into realistic work in a cooperative problem-solving environment; realistic evaluation; using teachers as helpers rather than direct instructors; specific educational goals; construction of knowledge; and it allows teachers to be learners (Lou, et al., 2011; Blumenfeld et al., 1991, Krajcik &

Blumenfeld, 2005). Project-based learning is a powerful pedagogy that emphasizes student learning (Major & Palmer, 2001) by transforming classrooms classrooms into active learning environments while students investigate significant questions and take responsibility for their learning while collaborating (Krajcik, Blumenfeld, Marx, & Soloway, 1994).

CHAPTER TWO: LITERATURE REVIEW

Chapter 2 provides a short review of literature in the area of STEM education, with a focus on Integrative STEM Education and career development. This chapter begins with a historical overview of STEM education that culminates with an introduction into Integrative STEM Education. It then goes into career development theory, with a special focus on child career development, and culminates with a discussion of the continuum of career and technical education.

The 21st Century has been home to great progress in both industry and education; however, school systems struggle to keep up with the pace with which our global marketplace is growing. Workforce development priorities in proficiencies have shifted in the 21st century due to the emergence of global economies (Trilling & Fadel, 2012; Wagner, 2008). Becoming career-ready and/or attending college often requires more from students than simply performing well academically now (Association for Career and Technical Education [ACTE], 2014); the task of career readiness should not just be a by-product of other school subjects, but rather a mission of schooling (Bloch, 1996; Herr, Cramer, & Niles, 2004; Lapan, 2004). As Crockett and his team pointed out, for students to progress from the foundations of learning, teachers need to expand their thinking outside their “primary focus and fixation on the Three Rs (3Rs)—beyond traditional literacy to an additional set of 21st century fluencies, skills that reflect the times we live in” (2011, p. 17). As it stands, the future of the American workforce is lacking in the 21st Century skills necessary to compete in the modern global workforce (Casner-Lotto & Benner, 2006). Unlike non-technical fields, STEM careers require a path of achievement that starts with math and science high school coursework (American Association of University Women [AAUW], 1998), known as the gatekeepers to advancement.

While careers in STEM fields include large sectors of our society, requiring various levels of formal education, many young people are unaware of the existence of STEM careers; a lack of knowledge of STEM careers can be one reason why students choose non-STEM career options. Students have a limited understanding of the various STEM work available (Bieber, Marchese, et al. 2005; Cleaves, 2005). STEM-specific career exploration can broaden students' awareness of STEM career opportunities. Given that students express attitudes about whether a STEM career was a viable choice by age nine (Joyce & Farenga, 1999), beginning explorations in elementary school is paramount to expanding the pipeline. Madill, Ciccocioppo, Stewin, et al. (2004) found that connecting STEM to real-world problems helps sustain students' interest and engagement in STEM coursework, and ultimately their persistence in post-secondary STEM study. By connecting career explorations to STEM education coursework, students can be helped in the short-term with an increase in interest and engagement, as well as long-term with additional career opportunities. The next step then, is to define STEM education and determine how to integrate career explorations into the process.

There are multiple definitions of STEM education (Breiner, Harkness, & Johnson, 2012; Ostler, 2012; Sanders, 2009) and even more approaches to its implementation (Dugger, 2010; Honey, Pearson, & Schweingruber, 2014). Historically, the National Science Foundation (NSF) has been the largest facilitator of STEM education reform (Wells, 2008). Coined "SMET" in the 1990's by the NSF, there have been various acronyms used in this body of research; and with all there has been a struggle to unite into a single body of work (Sanders, 2009).

Regardless of what it has been called at the time, there is a history of curricular reform efforts with regard to STEM education. The STEM education movement can be attributed to the "Space Age"; when the Russian satellite Sputnik launched in 1957, and a race for technological dominance began (Jolly, 2009; Sanders, 2009). This competition and feeling of immediacy gave way to long-term thinking and formal reforms were put in place. A Nation at Risk (National Commission of Excellence in Education, 1983), Science for All Americans (American Association for the Advancement of Science [AAAS], 1989), and Benchmarks for Science Literacy (AAAS, 1993) all worked toward increasing ability and interest in math science, and technology (Wells, 2013). The National Science Education Standards (NRC, 1996) promoted not just science, but engineering and technology concepts within science education. As we ushered in a new century, The Standards for Technological Literacy (International Technology Education Association [ITEEA], 2000; 2002; 2007) urged the integration of content areas using technological and engineering design as a vehicle. President Obama's "Educate to Innovate" ushered STEM initiatives into the limelight once again, and in 2011, the National Research Council's (NRC) A Framework for K-12 Science Education formally gave engineering content and practices a seat at the table through the Next Generation Science Standards (NGSS) (NRC, 2012).

In its current form, STEM education is often misunderstood. STEM education is not meant to be a catch all for anything math, or anything science, or anything using electronics, either. STEM education is meant to be about the connections between the content. Research shows us that curricula taught in siloed content areas "neither engages students nor prepares them for productive lives" (Brown, 2006, p. 777). When working with an integrated curriculum, students report being happier going to school, and researchers found students were more engaged (Smithirin & Upitis, 2005). Brown found that when engaged in integrated curriculum students "use thought processes", "think critically and creatively", "solve problems", work on interpersonal skills and communications, and "they can begin the process of becoming lifelong learners" (781-783). He also said that, "curriculum integration involves students in genuine democratic activities that can yield solutions to practical problems they experience" (781).

Operational differences aside, STEM educators can all agree on one thing- that effective STEM education is vital to ensure the future success of our students. That said, a growing number of people in the educational community take issue with the current condition of STEM education. Common criticisms include the content being a "mishmash of topics," disjointed subject matter from year to year, and a lack of coherence across subject matter domains (AAAS, 2000). Integrative STEM Education (I-STEM Education) can be a targeted remedy to this educational criticism. I-STEM Education is a way of reorganizing learning for students in the 21st century; it increases understanding, performance, and engagement with a more purposeful and relevant curriculum based on connections between the subjects and real-world problems. I-STEM education gives structure to curricula and ties topics from multiple content areas together in meaningful ways (Sanders, 2009; Sanders, 2012; Wells 2013). Topics are relevant to real-world problems, not a "mishmash" of random units that haven't been edited in 30 years.

At its core, I-STEM Education intentionally integrates "the concepts and practices of science and/or mathematics education with the concepts practices of technology and engineering education" (Sanders & Wells, 2006). Integration is a requirement. Therefore, a lack of coherence is impossible as the subjects are intertwined within the unit of instruction. Along the same lines, I-STEM Education is conceptually different from most current practices in that it is designed to be "thoughtfully and effectively articulated across multiple school grades/bands," (Sanders, 2012, p. 104). This statement alone negates the concerns about a lack of coherence between grade levels, but it is also meant to provide "a unique and powerful context for meaningfully organizing STEM knowledge for future retrieval/use" (Sanders, 2012, p. 109). This reinforces that coherence, as students continue to pull from their knowledge foundation from year to year.

Integrative STEM Education is a "design-based pedagogy that builds upon all that technology educators have learned about design-based instruction over the past two decades" (Sanders, 2012, p. 110). It is learning 2.0, students are engaged in real-world problems where their knowledge is meant to crossover and build transdisciplinary connections between different topics and atop their previous experiences. By incorporating real-world problems into the classroom, an opportunity is created to introduce the world of work to students in a functional way. Coursework that has career awareness activities or skills integrated into the curriculum (e.g., Colston, Thomas, Ley, Ivey, & Utley, 2017; Ernst, Bottomley, Parry, & Lavelle, 2011) is an effective career intervention at the elementary level. By actively experiencing different aspects and tasks associated with specific careers through active engagement, children gain important knowledge about themselves and the potential careers in an authentic manner, providing them more input with which to make a sound decision.

I-STEM Education opportunities offer opportunities for career exploration. By using real-world problems, teachers can easily integrate real job titles and functions into their unit. This connection aligns well with well with students in Super's (1957, 1990) Growth stage. Super's career development life span theory (1957, 1990) describes career development as a constantly evolving continuum in which people move through different stages. Super's Growth stage consists of three sub-stages: Fantasy (4-10 years) where role-playing is important, but needs dominate; Interest (11-12 years) where preferences are the major source of activities and aspirations; and Capacity (13-14 years) where the child considers abilities, training, and job requirements (Schultheiss, 2008). I-STEM Education adapts well to all three of these substages.

Howard and Walsh have a similar theory. In building out their model of children's conceptions of career choice and attainment (CCCA), Howard and Walsh (2011) integrate existing literature to create a picture of children's vocational thinking; it "begins with magical thinking, gradually evolves to include interests, and abilities and emphasize the activities or behaviors characteristic of an occupation, includes an understanding of training requirements, and finally understands careers as an ongoing, dynamic process" (p. 257-258). The CCCA organizes those conceptions by connecting them to three approaches to cognitive reasoning (each with two levels) that children use to reason out work-related process and choosing a career: Association, Sequence, and Interaction. Students' progress from "pure association" and "magical connection" (Association), to exploration through "external activities" and "internal processes and capacities" (Sequence), and finally into "interaction" and "systemic interaction," where the child considers their interests, abilities, preferences, and connection to the world at large. Figure 1 offers Howard and Walsh's (2011) provided descriptions of children's conceptions of career development by stage.

Practitioners and researchers alike should have a working knowledge of child career development theory to ensure content and pedagogical opportunities are aligned with student needs and developmental capabilities of children in the classroom. This knowledge, when combined with applied learning opportunities, offers an opportunity for maximum change in students STEM career interest. When CTE principles are merged with STEM career awareness initiatives, there are increases to both a students' understanding of STEM content and to interest in STEM career pathways (Hyslop, 2010). As mentioned earlier, CTE is applied technical learning integrated with rigorous academics to aid in the development of skills needed for success (ACTE, n.d.). It is a curricular sequence that promotes procedural and technical skills through application-based learning opportunities. Through preliminary exposure to this sequence at the elementary level, a stronger foundation can be set with regard to both ability and interest.

Figure 1. Summary description of Howard and Walsh's children's conceptions of career development (2011, p. 259)

Level 1: Pure Association

Job/career simply exists; Offers an unelaborated list of statements about the job/career when asked to describe career choice and attainment.

Level 2: Magical Connection

Simple method of career choice and attainment; no mechanism identified; career choice and attainment merely happen.

Level 3: External Activities

Simple process of learning about jobs, choosing based on interests. Description of external, observable, and learnable skills and/or activities that lead to attaining a job/career.

Level 4: Internal Processes & Capacities

Choice is a process of matching self to jobs/careers. Includes job activities, job/workplace characteristics, personal interests and abilities, considered in an additive manner. Attainment requires learning skills and having the ability to do the work.

Level 5: Interaction

Choice requires the consideration of interaction of personal attributes and environmental influences and has many possible outcomes. Attainment involves dynamic interaction of multiple factors at the personal, relational, and immediate environmental levels.

Level 6: Systemic Interaction

Choice requires the consideration of interaction of personal attributes, environmental influences, and systemic level factors (e.g., employment trends). Attainment involves dynamic interactions of factors at the personal, relational, environmental, and societal levels (e.g., emerging occupations such as green jobs).

CHAPTER 3: MANUSCRIPT 1

BUILDING STEM CAREER INTEREST THROUGH CURRICULUM TREATMENTS

Abstract

Watson and McMahon's (2005) work identified a need for research to examine the what and how of children's career development learning; this research is a start to answering that call, specifically focusing on STEM career interest as a precursor to development due to the current needs nationally for an increase in the STEM pipeline. This study examined the impacts of design-based learning and scientific inquiry curriculum treatments with embedded career content on the career interest of fifth-grade students as compared to traditional classroom methods. It found that there is an upward trend in interest with the use of these curriculum treatments, but it is not a significant change, likely due to the short time period of the unit and/or small *n*.

Introduction

Despite the fact that one in three American school children attend a rural school (Rural School Community Trust, 2003), in comparison to urban education, research on rural areas is scarce (Tieken, 2014). While research on STEM career interest and ability is on the rise, few efforts to expand and diversify the STEM workforce account for regional differences (an example would be Ali & Saunders, 2009). Research regarding career development in rural Appalachia, more than 1,000 miles and 420 counties in 13 states on the Eastern and mid-Atlantic region of the United States which is known for its poverty and unemployment rates, is even more rare (Ali & Saunders, 2009).

The Appalachian Access and Success Study ([AAS], Spohn, Crowther, & Lykins; 1992) found that cost and a students' academic ability, career goals, and their expectations for the future influenced students' decisions to pursue higher education (Spohn, Crowther, & Lykins;

1992). It also reported that social and academic under-preparedness and a student-perceived lack of intelligence to complete a college degree also contributed to the students' decisions not to pursue higher education. This lack of confidence in self and their schools may first be articulated at the high school level in literature, but that does not mean the problem begins there. It is systemic; real change must begin at the foundation of a student's education- elementary school. By changing the educational practices early on, students can build higher self-efficacy levels that can sustain them through their high school careers, which is beneficial since self-efficacy beliefs independently predict Appalachian youth's expectations to attend college (Ali & Saunders, 2006). These self-efficacy levels, in turn, affect their STEM attitudes, which is a major component in STEM career development.

Career Development in Children

Career development in children is dynamic and interactional (Watson & McMahon, 2005). In the empirical research found, children begin framing ideas and making judgments about their future occupations, and that vocational knowledge was a significant predictor of career aspirations and expectations, as early as four years old (Schmitt-Wilson & Welsh, 2012; Trice & Rush, 1995). While it starts early, career development and choice is a complex process that involves numerous factors that may play a role in a child's decision-making process, and becomes more complex over time; the children themselves cannot always identify the factors that have contributed to their career aspirations, that ability appears to emerge over time (Trice, Hughes, Odom, Woods & McClellan, 1995). Developmental patterns of progression like this are present throughout the literature on student career choice. Research on factors that influence children's career aspirations has uncovered a multitude of contextual and environmental, interpersonal, and intrapersonal factors that impact and shape children's career aspirations. These systemic factors are a mix of overt and covert influencers of career choice across student age groups (e.g., the need for money, McMahon & Patton, 1997, Howard, Flanagan, Castine, & Walsh, 2015; Phipps, 1995), as well as some that appear at specific developmental stages (e.g., role models are identified as being influential as early as third grade, Phipps, 1995; or in high school, students consider the developmental nature of a career, Borgen & Young, 1982). Parker & Jarolimek (1997) found that when young people map out their futures, they tend to choose professions that are familiar, and knowledge of career options in general is necessary for students (Skolnik, 1995). The factors researched are numerous and varied, which is understandable given the complexity of the process, as a field we look to literature reviews for a compilation of findings.

Recent reviews of childhood career development research (Hartung Porfeli, & Vondracek, 2005; Watson and McMahon, 2005) compile the empirical research and provide a macro-view of childhood career development; they will be discussed next. Collectively, they provide a clear focus on career aspirations and expectations; the amount of knowledge children have about careers, the world of work, and themselves; and important factors relevant to how and when student career choice develops. This study is structured around two well-cited reviews.

Hartung, Porfeli, and Vondracek's (2005) review uses a life span developmental framework to consolidate previous empirical research on childhood career development, with a focus on early to late childhood (3-14 years); this aligns with Super's career development life span theory (1957, 1990). Super's Growth stage consists of three sub-stages: Fantasy (4-10 years) where role-playing is important, but needs dominate; Interest (11-12 years) where preferences are the major source of activities and aspirations; and Capacity (13-14 years) where the child considers abilities, training, and job requirements (Schultheiss, 2008). We need to understand this breakdown to ensure selected career connections are developmentally appropriate.

Through a content analysis of existing literature, Hartung, et al.'s (2005) review is organized in five dimensions: career exploration, career awareness, vocational expectations and aspirations, vocational interests, and career maturity/adaptability. The authors find that steady progress across these five dimensions aligns with the shift from vocational to career exploration, "a process that begins as an orientation to the world-of-work and becomes an examination of the self within the world-of-work coupled with overt behavior in support of this process" (Hartung, et al., 2005, p.390). This vocational development, a part of career choice, begins much earlier in the life span than assumed (as early as 4 years old), and affects the choices they make as adolescents and young adults with regard to their future careers. Hartung, et al. (2005) conclude the perception of children's career development as a passive process needs to change to that of an interactive process in which children engage with the world-of-work. They also find that, "Preliminary evidence suggests that steady progress in vocational exploration, awareness, aspirations and expectations, interests, and adaptability during childhood facilitates the development of personal identity and connectedness to the social and interpersonal world" which is important not just for career choice, but also holistically for the child as it may reduce delinquent and deviant behaviors (p. 411). This is important to note because there is a gap in research and practice; currently, research shows that starting early is beneficial to career development, but prior to the secondary level, most schools do not incorporate career development into their programming.

Watson and McMahon (2005) structured their review of research on career development in children using learning as a unifying theme, examining 76 articles relevant to the career development of children up to 13 years old that span from 1971 to 2003, including seven previous reviews. They see career development as having a “dynamic and interactional nature;” by using learning as a unifying theme, we can “understand more holistically the influences on and the process of career development learning” (p. 119). They argue there is a need for dual focus research to examine the what and how of children’s career development learning. Watson and McMahon (2005) suggest that in relation to career development, children’s learning is a recursive process between the child and their social and environmental constructs, such as family, home environment, school, media, ethnic background, and society. They also note a relative absence of childhood research on intrapersonal constructs such as self-concept, self-efficacy, career maturity, and values, which are common factors explored in adult career choice. This recursive nature is important to note; students’ attitudes and beliefs are constantly evolving, and as such, effective career development efforts need to be structured to account for this with recurring learning opportunities.

Career development, while on the way to career choice, proceeds along a continuum and through an increasingly complex process where numerous factors play a role in a child’s decision-making process, including a multitude of interpersonal, intrapersonal, environmental, and contextual factors. An essential part of this process is gaining the knowledge of career choices available (career awareness) and interest to the child; this is happening concurrently in all parts of the child’s life, to include home, school, and their community at large. School is a large part of a student’s daily life, inclusion of career development here has the potential to make a difference in their later outcomes.

Career awareness follows a developmental course beginning in early childhood (Dorr & Lesser, 1980; Hartung, et al., 2005). At fifth grade, students are at a stage where their vocational thinking include interests and abilities but are also starting to consider the activities or behaviors characteristic of an occupation (Howard & Walsh, 2011), so this information should be integrated into curriculum. Active engagement is one form of interaction with the world-at-large that students learn about potential career choices from. By 10 years old, children rely on their own experiences when considering future careers. Opportunities such as hobbies, after-school jobs or activities, and the school itself all offer opportunities to explore careers of interest (Seligman, Weinstock, & Heflin,1991). At school, there are a variety of effective elementary career interventions noted in research, such as: action-oriented classroom guidance activities (e.g., Beale, 2000; Beale, 2003; Brathwaite, 2002); role playing (Super, 1957; Beale, 2003), or coursework that has career awareness activities or skills integrated into the curriculum (e.g., Ernst, et al., 2011; Capobianco, Diefes-dux, Mena, & Weller, 2011). By actively trying on different aspects and tasks associated with specific careers through active engagement, children gain essential knowledge about themselves and the potential careers in an authentic manner, providing them more input with which to make a sound decision.

In summary, influence and experience are found in the home, school, and community at large; they are continually providing input to the student, and as the student progresses developmentally, they are mentally prepared to reflect and assign meaning to the input, which in turn helps them in their career choice. Watson and McMahon suggest that in relation to career development, children's learning is a recursive process between the child and their social and environmental constructs, such as family, home environment, school, media, ethnic background, and society (e.g., socioeconomic status and gender role socialization) (Watson & McMahon, 2005; Schultheiss, 2008). This is supported by the empirical studies discussed above. They also point out the need for research to examine the what and how of children's career development learning; this research is a start to answering that call, specifically focusing on STEM career interest as a precursor to development due to the current needs nationally for an increase in the STEM pipeline.

In combining the issues of rural education and career interest experiences, a study was initiated to investigate the impact of hands-on science units with embedded career connections have on elementary students STEM career interest in Radford City Schools. Two curriculum treatments were identified for this study, scientific inquiry and design-based learning, and paired with a control group that used a traditional science unit. In a traditional pedagogy-based classroom, after passively receiving information, students are assigned tasks that have little resemblance to professional practices. However, learning is less concerned with what learners do, and more what they know and how they come to acquire it (Jonassen, 1991; Uden & Beaumont, 2006). Therefore, it is less about the activity, and more about the potential the activities hold for student knowledge and knowledge acquisition. DBL has the potential to enhance students' success in science class by increasing students' desire to learn and students' interest in science topics (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008) as well as their efficacy and attitudes relating to STEM concepts (Ernst, Bottomley, & Parry, 2012). Under the right circumstances, scientific experiments can be effective in promoting intellectual development, inquiry, and problem-solving skills (Tamir, 1991; Tobin, 1990).

While both experimental treatment methods benefit students, they do so by focusing on different academic, scientific, and non-cognitive skills. In the *Taking Science to School* report (2007), Duschl suggested that science education research is based upon curricular resources that do not align with National Science Education Standard goals to promote science literacy for all students and old-fashioned views of learning. Both scientific inquiry and design-based learning counteract that in unique ways. In the classroom, design-based learning "enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles, and various skills" (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008). With scientific inquiry, students learn to embody a set of values; these "values include respect for the importance of logical thinking, precision, open-mindedness, objectivity, skepticism, and a requirement for transparent research procedures and honest reporting of findings" (NRC, 2012, p.248). So, while there are specific differences between the two methods, both support knowledge construction and important scientific skills.

Research Question

This research study was designed to investigate and identify the impacts, if any, that design-based learning and scientific inquiry curriculum treatments with embedded career content have on the career interest of fifth grade students. To guide this investigation, one overarching research question was posed:

1. What differences in career interest are demonstrated when Scientific Inquiry, Design-Based Learning, or a traditional science unit are used?

This research examined curriculum treatment implementation through a quasi-experimental design, which consisted of experimental/treatment and control features to measure career interest using random assignment. The primary intent is to gauge the effectiveness of active learning curriculum treatments with embedded career connections as an opportunity to affect vocational thinking in efforts to further inform teacher practices.

Methodology

Participants

Radford falls squarely in a region known as south-central Appalachia (Appalachian Regional Commission, 2010), where, at 27.5%, the poverty rate is near twice the national average and it has less than the national average of college graduates, 27% compared to 46% nationally (U.S. Census Bureau, 2011). This area is part of an "invisible minority because they do not appear outwardly different from mainstream Americans" (Tang & Russ, 2007, p. 34). Students in this region are under-represented in STEM fields, even at the Universities that lie within its borders, and then later in STEM fields regardless of whether they require a degree.

Participants in this study were fifth graders enrolled at the county's upper elementary school, Belle Heth Elementary, during September 2017. Belle Heth is a state-identified Title I focus school as 26% of students receive Title I services. All six fifth-grade classes participated in the study, with two classrooms assigned to each group. To control for differences in teacher STEM efficacy, and ensure internal validity, teachers were grouped by score (high and low) on their T-STEM before their classes were randomly assigned to a treatment; each treatment received a high-efficacy and low-efficacy teacher. Each class included between 18 and 23 students. Students whose parents consented to their participation and who also agreed were given the S-STEM survey, 25 students from the 126 fifth graders declined to participate, and 21 students had incomplete data, so there were 82 participants. Within the study, there were 40 female and 42 male students, 78% identified as white, and 56.1 percent of the students received free/ reduced-price lunch (see Table 1).

Table 1. Student Demographic Characteristics

Demographic Characteristic	Percentage of Respondents Traditional (n=32)	Design-Based Learning (n=21)	Scientific Inquiry (n=29)	TOTAL (n=82)
Gender				
Male	43.8%	61.9%	51.7%	51.2%
Female	56.3%	38.1%	48.3%	48.8%
Ethnicity				
White/Caucasian	81.3%	85.7%	69.0%	78.0%
Ethnic Minority	18.8%	14.3%	31.0%	22.0%
Free/Reduced Lunch				
Receives	62.5%	61.9%	55.2%	56.1%
Does not receive	37.5%	38.1%	44.8%	43.9%

Curriculum Treatments

For the purposes of this study, there were three treatment groups: traditional, design-based learning, and scientific inquiry. In this project, the traditional unit consisted of PowerPoint presentations and worksheets as prescribed by the county's curriculum guide. Experimental groups experienced the same material, differently. With both experimental groups, there was a focus on active learning methods to increase student engagement in the material (Prince, 2004; Gleason, Peeters, Resman-Targoff, Karr, McBane, Kelley, & Denetclaw, 2011) and tying the material to specific career areas via quick connections. Example of a quick connection found embedded in the slides are "Work with your assigned research partner and compare notes... Timeliness is important in science, and you don't want to miss out on the next assignment." or "Work with your design team and share your notes... Deadlines are important in engineering, and you don't want to miss out on the next assignment." These quick connections draw attention to how the student's current work in the classroom relates to the expectations within the career area.

When the active learning strategies and career connections come together, the student has the opportunity to experience different career areas while engaging in the content. For example, on day 6, all three groups covered food webs, but each group's experience was different. Table 2 shows the differences between the group's day in more detail, but in general, the control group spent an hour working through a PowerPoint and several worksheets, while the scientific inquiry group listened to science parodies with lyrics screening on YouTube and then began identifying and analyzing a marine food web, while the DBL group did a review of their truncated lesson the day before, and was then introduced to the engineering design process while building and testing a spider web prototype. The day prior, all three groups had spent in lecture, again with slight modifications for the treatment groups. After a work check and hands-on warm-up, the DBL group had the bulk of the required food web material in a condensed version of the traditional slides to make time for their design challenge. Whereas, having completed a mini-activity on lab reports on day 4, the scientific inquiry group's adapted slide deck was paced more similarly to the traditional group, still using their journal instead of standalone worksheets.

While both scientific inquiry investigations/experiments and design challenges are forms of hands-on learning, there are very clear differences and benefits to each. Pragmatically, in the design challenge activity, students will be provided a problem and asked to collaborate in small groups (3-4) to engage the engineering design process and create a solution. Students will be provided an engineering notebook to sketch ideas, materials to use in building their artifact, and a list of criteria and constraints to adhere to. To prepare for their activity, students practiced and explored critical thinking and the engineering design process. Whereas in the scientific inquiry experiment, student pairs conducted investigations to test questions about the natural world by engaging the scientific method. Students were provided a lab notebook, materials to use in their scientific experiments, and a basic experiment framework to test their hypothesis. To prepare for their activity, students practiced and explored measurement, analysis, and critical thinking. The artifact was not a solution (no problem is presented), but rather an evidence-based lab report that supports their conclusions and a rationale that connected the evidence to the claim. Table 3 gives a comparison of the three represented curricula types. To summarize, in the design challenge, students used the engineering design process (PBSkids, n.d.) to physically construct an artifact/solution to the problem presented; while in the scientific inquiry experiment, students conducted investigations through scientific inquiry, then used their results to articulate an explanation in terms of scientific concepts and principles, and the traditional group completed a lecture-based unit.

Table 2. Day 6 Material Comparison

	Warm-Up	Activity	Wrap-up
Traditional	8-10 minutes complete Food Web worksheet while listening to Mr. Parr songs	40 minutes Review slides and videos on food chains and food web. 5 minutes Then place provided cards into a food chain for teacher to check.	5 minutes complete Food Chain Worksheet
Scientific Inquiry	8-10 minutes Listen to Mr. Parr songs * Food Chain * Energy Flow	35 minutes quick intro then into marine food web activity- document energy flow and reinforce vocabulary and numerical representations with a tally chart and bar graph for formative assessment	5 minutes review life cycles via slides
Design-Based Learning	8-10 minutes Listen to Mr. Parr songs * Food Chain * Energy Flow	5 minutes review food web from previous day 30 minutes* spider web design challenge- introduce the engineering design process to build and test a spider web that catches multiple-sized bugs.	5 minutes review life cycles via slides

*Note: One class opted to continue iterating their designs during a break, however requirements were met prior to that.

.

Table 3. Comparison of Curriculum Treatments

	Traditional	Scientific Inquiry	Design Challenge
Groups	Single-student	Pairs (2)	3-4 students
Materials	Worksheets, printed PowerPoint slides	Lab notebook, materials to use in their scientific experiments, and a basic experiment framework	engineering notebook to sketch ideas, materials to use in building their artifact, and a list of criteria and constraints
Student Preparation	Memorization of facts	Critical thinking, measurement, analysis	Critical thinking, engineering design process
Basis	Traditional collection of identified material	Scientific method	Engineering design process
Process	Teacher-centered lecture	conduct investigations to test questions about the natural world	engage the engineering design process and create a solution to the problem at hand
Artifact	unit test	Lab report + unit test	Constructed solution + unit test
Benefits	Efficiency; ability to tailor to standards provided by the state.	build values, including "respect for the importance of logical thinking, precision, open-mindedness, objectivity, skepticism, and a requirement for transparent research procedures and honest reporting of findings" (NRC, 2012, p.248)	"enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles, and various skills" (Doppelt, et al., 2008).

Sequence of Events

The RCPS science pacing guide allots nine school days to the living systems unit; given that a long-term goal of project staff is to provide the school system with a sustainable Integrative STEM curriculum, units provided should be comparable in time frames. Therefore, the curriculum plans for each treatment were based around the currently allotted nine days. The control group completed the unit as prescribed in the current pacing guide, with only the addition of a pre-test on day one being added to the curriculum plan. Both the scientific inquiry group and the design-based learning group went through a condensed version of the traditional curriculum, and completed two small applied learning exercises designed to prepare the students for their activity period being completed on days 2-6. On day 7, both experimental groups used a double period to complete either their design challenge or science experiment; to keep class times similar between the three groups, this time was allocated by not holding class on day 1 of the study for those two groups. All three groups completed their unit test and the project's post-survey on day 9. An enrichment day where all students partook in the hands-on components they had not yet received was held on day 10 after data completion ended.

Table 4 shows the layout of how each of the major events occurred for each group, including the pre-test, lesson plans by topic, the design challenge, scientific inquiry investigation, and unit test. As mentioned above, day 10 is not part of the official unit; the study and timeline were designed so that each student will get to participate in the design build, including the control and scientific inquiry groups after they have finished their traditional unit and subsequent testing. This is to ensure equality for the students and as a thank you for the student and teacher efforts in the study.

Table 4. Comparison of Unit Pacing by Treatment

Day	Traditional Method	Scientific Inquiry	Design-Based Learning
Day 1	populations, communities and ecosystems habitats and niches	none	none
Day 2	populations, communities and ecosystems habitats and niches	populations, communities and ecosystems habitats and niches	populations, communities and ecosystems habitats and niches
Day 3	adaptations	adaptations	adaptations
Day 4	adaptations	adaptations*	adaptations*
Day 5	food webs	food webs	food webs*
Day 6	food webs	food webs* niche and life cycle	food webs* niche and life cycle
Day 7	niche and life cycle	experiment	design challenge
Day 8	human influence	review connect activity to human influence	review connect activity to human influence
Day 9	unit test and post-survey	unit test and post-survey	unit test and post-survey
Day 10 (Enrichment)	experiment design challenge	design challenge	experiment

Note: experimental groups did not hold class on day 1 to provide a double period on day 7 while ensuring equality of class time across the groups. * mini activities were completed

As discussed above and seen in Table 4, while each unit plan is nine periods long, there is an intentional difference in the unit's pacing for each of the project's three groups (control, scientific inquiry, and design-based learning). While all groups progress through the sequence of lessons in the same order and ultimately spend the same amount of class time on the unit, the amount of time spent on each topic differs between the control and experimental groups. All teachers had access to the same content, just presented in a different way to account for the introduction of careers and active components of the experimental groups. All three curricula were aligned to the original unit's goals; testing was designed as a Virginia SOL review, the majority of questions were previously released questions from the state.

Procedures

After approval from the University's human subjects review board was secured, teachers were administered the T-STEM in August. Teachers were rank ordered based on their overall score on the T-STEM and then divided into a low and high group, three teachers in each, however there was a close separation between the third and fourth ranks. The overall scores between the two middle-scoring teachers had a difference of only three points (<1% of the possible total points), so the Elementary STEM Instruction subtest was used to confirm groupings, where there was a seven percent difference in scores that confirmed the existing rank order of the teachers. One teacher from both the high and low groups were then randomly assigned to either the control, scientific inquiry treatment group, or design-based learning treatment group.

Students brought home letters explaining the study along with a copy of the informed consent document in their initial paperwork packet that goes home at the start of the school year. Written student consent, signed by both parent and student, was collected from students before completing their pre-test at the start of the ecosystems unit, which took nine school days to complete. Unit pre- and post-tests were completed with a traditional paper format; all students' utilized the same tests. The S-STEM responses were collected via a Google Form, Belle Heth leverages Google products in the classroom so students were familiar with this format. Following the post-test, an additional day was allocated for enrichment activities in which the control group completed an abbreviated scientific inquiry lab and the design challenge, and the experimental group completed either the lab or challenge they had not yet completed.

During the unit, the researcher spent an equal number of days in each classroom to prevent resentful demoralization of the control group. As described in previous sections, each group had a variation of the same curriculum; the control group used the school's traditional curriculum and pacing guide, to and to make space for the lab or design challenge, the experimental groups used an abbreviated version of the same curriculum with an altered pacing (see Table 4).

Ensuring Validity

Inherent in all classroom-based studies is a certain amount of variability in teaching practices between treatment groups. Differences in subject characteristics is an internal validity concern to all studies, and nearly half of studies do not address it properly (Horton, McConney, Woods, Barry, Kraut, & Doyle, 1993). In this study, there was concern about how to account for the natural variability in teaching practices between the treatment groups. To control the potential bias, several safeguards will be put into place. First, the project staff used the T-STEM, as described above, to measure teachers' STEM efficacy and use the scores as part of the grouping assignments; teachers will be assigned to the high or low efficacy group (three teachers in each), and then one high efficacy and one low efficacy teacher were randomly assigned to each treatment. Additionally, all teachers used the assigned curriculum, which included daily presentations, activities, worksheets, and homework when applicable, and a pacing guide to stay on target. The researcher was present in teacher classrooms at the start of the school year, and for four of the nine days the unit was taught either observing or co-teaching. So, the factors relating to variability in teaching practices that might have affected outcomes should be equivalent across intervention conditions, and do not pose major threats to the internal validity of the present study.

The Hawthorne effect is a concern for all field experiments, present in 48 percent (Horton, et al., 1993); it can be defined "the problem in field experiments that subjects' knowledge that they are in an experiment modifies their behavior from what it would have been without the knowledge" (Adair, 1984, p. 334). When applied to teaching situations like those in this study, the Hawthorne effect can have positive implications. Simply stated, "when a person becomes convinced that what he is doing is important, he will try to do it better"; therefore, project staff will use intentional language to show the teachers that their efforts in the study are important "in a direct way" to the school's well-being, "that their performance in front of their students on any day, in fact every day, is important" (Armenti & Wheeler, 1978, p. 123). Of course, the Hawthorne effect could affect student results; however, this is being controlled for by having the project staff present regularly throughout the school year before the study begins, so the novelty will be less a concern, as the project staff will be viewed as a regular fixture in every classroom, including the control groups' (Adair, 1984). So even if the Hawthorne effect was to be of concern for student scores, it would be even across all groups, and therefore there would be no special attention concerns, and awareness of experiment participation would be evenly distributed between all the students (Adair, 1984).

Instruments

S-STEM. The study measured student career interest using the Upper Elementary School (4-5th) S-STEM Survey (Friday Institute for Educational Innovation, 2012). The S-STEM instructs student that "As you read about each type of work, you will know if you think that work is interesting" and then has students score their attitudes toward 12 STEM-based career areas using a Likert scale ranging from 1(not at all interested) to 4(very interested). The career areas include: physics, environmental work, biology, veterinary work, mathematics, medicine, earth science, computer science, medical science, chemistry, energy/electricity, and engineering; each career area includes a short, age appropriate, description. The instrument's reading level was analyzed by 10 upper elementary teachers, who indicated that the surveys were at an appropriate length and difficulty for students (Unfried, Faber, Stanhope, & Wiebe, 2015). In addition to measuring STEM career interest, the S-STEM is designed to measure changes in students' confidence and efficacy in STEM subjects (their STEM attitudes) and 21st century learning skills, however these responses are not within the scope of this study.

School records. Student demographic information was collected from school records to provide a picture of the population, to include student age, sex, race/ethnicity, IEP and 504 statuses, gifted program status, and free/reduced-rate lunch status.

T-STEM. This study utilized the elementary teacher version of the Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey to measure teachers' STEM career awareness and their science and math teaching efficacy and beliefs and expected outcomes. Cronbach alphas of the utilized subscales ranged from .814 to .945.

Results

In order to answer the research question (What differences in STEM career interest are demonstrated when scientific inquiry, design-based learning, or a traditional science unit are used?), students were asked to score their attitudes toward 12 STEM-based career areas using a Likert scale ranging from (1) "not at all interested" to (4) "very interested" on the last day of the unit (day 9). These responses, along with the demographic data, were cleaned and compiled into SPSS, and then examined for data entry accuracy, missing values, and outliers; 82 of the 101 participants had complete data for the areas being examined and were retained for the analyses. To assess the curriculum treatments' impact on STEM career interest, an analysis of variance

(ANOVA) on career interest by curriculum treatment was conducted. An ANOVA has six assumptions that must be met, this study's data is addressed for fit below:

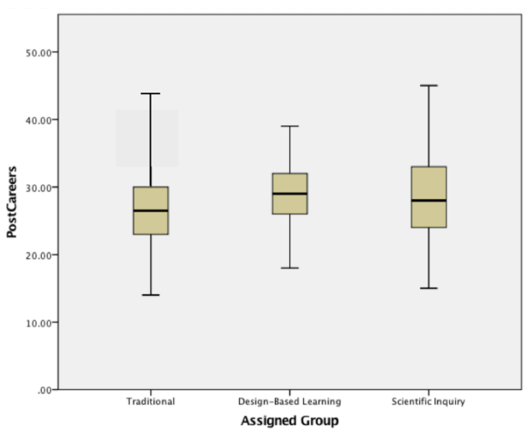
1. one dependent variable measured at the continous level- per Norman (2010) and Gaito (1980), Likert scale responses can be used in an ANOVA as the dependent variable. The subtest total was also analyzed, which is a traditional continuous variable.
2. A categorical independent variable- the assigned treatment group variable is categorical and contains three groups.
3. independent observations- there is no relationship between the observations in each group of the independent variables or between the groups themselves.
4. no significant outliers- There were no outliers, as assessed as being greater than 3 box-lengths from the edge of the box in a boxplot.
5. dependent variable is approximately normally distributed- Data for the career subtest was normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). Other areas had a p-value of greater than .05. However, calling on previous research, Norman (2010) finds, "both theory and data converge on the conclusion that parametric methods examining differences between means, for sample sizes greater than five, do not require the assumption of normality, and will yield nearly correct answers even for manifestly non-normal and asymmetric distributions like exponentials." So, while the individual question Likert scale responses are not normally distributed, this is to be expected given the topic and the ANOVA will still be used because it is robust to deviations from normality.
6. variance of dependent variables is equal- There was homogeneity of variances for all career areas except mathematics (p=.027), as assessed by Levene's test for equality of variances, p >.05.

Analysis of Variance (ANOVA)

As there was an overall statistically significant difference in group means (p=.043) for the engineering career area, a Tukey's Post Hoc analysis was conducted to confirm where the differences occurred between groups. Effect size was calculated using eta squared, which is equal to partial eta squared in a one-way ANOVA (Levine & Hullett, 2002).

As mentioned above, a one-way ANOVA was conducted for each of the twelve measured career areas to determine if career interest score was different for different treatment groups. Participants were classified into three groups: traditional (n = 32), scientific inquiry (n = 29), and design-based learning (n = 21). There were no outliers at 3 box-lengths from the edge of the box, as assessed by boxplot (See Figure 1); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances (engineering p = .999). Data is presented as mean ± standard deviation.

Figure 1. Boxplot of Career Areas Subtest Scores



Within the ANOVAs conducted, there was not a significant main effect for the career areas of physics $F(2, 79) = .355$, $p = .703$; environmental work $F(2, 79) = 1.157$, $p = .320$; biology $F(2, 79)$ = .1.081, $p = .344$; veterinary work $F(2, 79) = .098$, $p = .907$; mathematics $F(2, 79) = .195$, $p = .824$; medicine $F(2, 79) = 1.607$, $p = .207$; earth science $F(2, 79) = .239$, $p = .788$;

computer science $F(2, 79) = .266$, $p = .767$; medical science $F(2, 79) = .318$, $p = .728$; chemistry $F(2, 79) = .505$, $p = .605$; or energy/electricity $F(2, 79) = .824$, $p = .443$. The career interest score for engineering was statistically significantly different between different treatment groups, $F(2, 79) = 3.281$, $p < .05$, with a small effect size ($\eta^2 = .077$). Interest in an engineering career area increased from the scientific inquiry ($n = 29$, $M = 42.55$, $SD = 0.948$), to traditional ($n = 32$, $M = 2.75$, $SD = .95$), to design-based learning ($n = 21$, $M = 3.24$, $SD = .944$) groups, in that order. Tukey post hoc analysis revealed that the mean increase from the scientific inquiry to design-based learning group (.686, SE=.272) was statistically significant (p=.036); no other group differences were statistically significant at .05 α.

Crosstabulations

After the ANOVAs were completed, a more detailed examination of the score spread was completed on each career area via a cross tabulation of proportion of scores. Physics is introduced to students on the S-STEM with the following passage: “People study motion, gravity and what things are made of. They also study energy, like how a swinging bat can make a baseball switch directions. They study how different liquids, solids, and gas can be turned into heat or electricity. These are topics in the field of Physics.” Across all groups, students were more likely to have little to no interest in physics as a career area, selecting (1) “not at all interested” or (2) “not so interested” rather than (3) “interested” or (4) “very interested.” Less than 10 percent of students in any group said they were “very interested” in a career in physics (see table 5). Within the traditional group, 34.4% of students identified as (3) “interested” or (4) “very interested” in physics as a career, as compared to 38.1% of students assigned to the DBL group and 27.5% of students assigned to the scientific inquiry group (see table 5).

Table 5. Physics Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	21.9%	43.8%	25%	9.4%	100%
Design-Based Learning, *n*=21	28.6%	33.3%	28.6%	9.5%	100%
Scientific Inquiry, *n*=29	27.6%	44.8%	24.1%	3.4%	100%
Total	25.6%	41.5%	25.6%	7.3%	100%

Environmental work is introduced to students on the S-STEM with the following passage: "People study how nature works. They study how waste and pollution affect the environment. They also invent solutions to these problems. These are the foundation of environmental work." Students in the traditional group were more than twice as likely to be (1) "not at all interested" in environmental work when compared to both design-based learning and scientific inquiry groups (see Table 6). Within the traditional group, 40.7% of students identified as (3) "interested" or (4) "very interested" in environmental work as a career, as compared to 33.4% of students assigned to the DBL group and 62% of students assigned to the scientific inquiry group (see Table 6).

Table 6. Environmental Work Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	25%	34.4%	31.3%	9.4%	100%
Design-Based Learning, *n*=21	9.5%	57.1%	28.6%	4.8%	100%
Scientific Inquiry, *n*=29	10.3%	27.6%	58.6%	3.4%	100%
Total	15.9%	37.8%	40.2%	6.1%	100%

Biology is introduced to students on the S-STEM with the following passage: “People work with animals and plants and how they live. They also study farm animals and the food that they make, like milk. They can use what they know to invent products for people to use. These are topics in biology.” Likert scores across the three groups were similar for the area of biology (see Table 7). Within the traditional group, 40.6% of students identified as (3) “interested” or (4) “very interested” in biology as a career, as compared to 57.2% of students assigned to the DBL group and 62% of students assigned to the scientific inquiry group (see Table 7).

Table 7. Biology Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	21.9%	37.5%	28.1%	12.5%	100%
Design-Based Learning, *n*=21	14.3%	28.6%	42.9%	14.3%	100%
Scientific Inquiry, *n*=29	13.8%	24.1%	44.8%	17.2%	100%
Total	17.1%	30.5%	37.8%	14.6%	100%

Veterinary work is introduced to students on the S-STEM with the following passage: “People who prevent disease in animals. They give medicines to help animals get better and for animal and human safety. This is veterinary work.” Those in the traditional group were twice as likely to be (1) “not at all interested” in veterinary work, as compared to the DBL group. Those in the DBL group also had the highest chance of being (4) “very interested” in this career area. Of those that showed an interest in veterinary work within the DBL group, there was a higher chance of the student being “very interested” than “interested” when compared to the other two groups (see Table 8). Within the traditional group, 53.2% of students identified as (3) “interested” or (4) “very interested” in veterinary work as a career, as compared to 38.1% of students assigned to the DBL group and 58.6% of students assigned to the scientific inquiry group (see Table 8).

Table 8. Veterinary Work Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	28.1%	18.8%	34.4%	18.8%	100%
Design-Based Learning, *n*=21	14.3%	47.6%	9.5%	28.6%	100%
Scientific Inquiry, *n*=29	17.2%	24.1%	44.8%	13.8%	100%
Total	20.7%	28%	31.7%	19.5%	100%

Mathematics is introduced to students on the S-STEM with the following passage: "People use math and computers to solve problems. They use it to make decisions in businesses and government. They use numbers to understand why different things happen, like why some people are healthier than others. This is mathematics work." Within the traditional group, 37.5% of students identified as (3) "interested" or (4) "very interested" in mathematics as a career, as compared to 52.3% of students assigned to the DBL group and 48.2% of students assigned to the scientific inquiry group (see Table 9).

Table 9. Mathematics Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	25%	37.5%	15.6%	21.9%	100%
Design-Based Learning, *n*=21	19%	28.6%	33.3%	19%	100%
Scientific Inquiry, *n*=29	20.7%	31%	31%	17.2%	100%
Total	22%	32.9%	25.6%	19.5%	100%

Medicine is introduced to students on the S-STEM with the following passage: “People learn how the human body works. They decide why someone is sick or hurt and give medicines to help the person get better. They teach people about health, and sometimes they perform surgery. This is the practice of medicine.” Within the traditional group, 28.2% of students identified as (3) “interested” or (4) “very interested” in medicine as a career, as compared to 19.1% of students assigned to the DBL group and 48.3% of students assigned to the scientific inquiry group (see Table 10).

Table 10. Medicine Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	37.5%	34.4%	9.4%	18.8%	100%
Design-Based Learning, *n*=21	47.6%	33.3%	4.8%	14.3%	100%
Scientific Inquiry, *n*=29	27.6%	24.1%	27.6%	20.7%	100%
Total	36.6%	30.5%	14.6%	18.3%	100%

Earth science is introduced to students on the S-STEM with the following passage: “People work with the air, water, rocks and soil. Some tell us if there is pollution and how to make the earth safer and cleaner. Other earth scientists forecast the weather. This is called earth science.” Within the traditional group, 28.2% of students identified as (3) “interested” or (4) “very interested” in earth science as a career, as compared to 42.8% of students assigned to the DBL group and 37.9% of students assigned to the scientific inquiry group (see Table 11).

Table 11. Earth Science Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	18.8%	53.1%	18.8%	9.4%	100%
Design-Based Learning, *n*=21	19%	38.1%	33.3%	9.5%	100%
Scientific Inquiry, *n*=29	13.8%	48.3%	31%	6.9%	100%
Total	17.1%	47.6%	26.8%	8.5%	100%

Computer science is introduced to students on the S-STEM with the following passage: "People write instructions to run a program that a computer can follow. They design computer games and other programs. They also fix and improve computers for other people. This is computer science." Within the traditional group, 50% of students identified as (3) "interested" or (4) "very interested" in computer science as a career, as compared to 47.6% of students assigned to the DBL group and 44.8% of students assigned to the scientific inquiry group (see Table 12).

Table 12. Computer Science Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	18.8%	31.3%	28.1%	21.9%	100%
Design-Based Learning, *n*=21	19%	33.3%	23.8%	23.8%	100%
Scientific Inquiry, *n*=29	31%	24.1%	24.1%	20.7%	100%
Total	23.2%	29.3%	25.6%	22%	100%

Medical science is introduced to students on the S-STEM with the following passage: "People study human diseases and work to find answers to human health problems. This is medical science." Within the traditional group, 21.9% of students identified as (3) "interested" or (4) "very interested" in medical science as a career, as compared to 23.8% of students assigned to the DBL group and 41.4% of students assigned to the scientific inquiry group (see Table 13).

Table 13. Medical Science Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	31.3%	46.9%	9.4%	12.5%	100%
Design-Based Learning, *n*=21	38.1%	38.1%	9.5%	14.3%	100%
Scientific Inquiry, *n*=29	34.5%	24.1%	27.6%	13.8%	100%
Total	34.1%	36.6%	15.9%	13.4%	100%

Chemistry is introduced to students on the S-STEM with the following passage: "People work with chemicals. They invent new chemicals and use them to make new products, like paints, medicine, and plastic. This is chemistry." While the percentages vary somewhat, the response pattern for each group is similar, with the bulk of students responding (1) "not at all interested" or (2) "not so interested". Within the traditional group, 37.5% of students identified as (3) "interested" or (4) "very interested" in chemistry as a career, as compared to 28.5% of students assigned to the DBL group and 41.4% of students assigned to the scientific inquiry group (see Table 14).

Table 14. Chemistry Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	15.6%	46.9%	25%	12.5%	100%
Design-Based Learning, *n*=21	23.8%	47.6%	19%	9.5%	100%
Scientific Inquiry, *n*=29	20.7%	37.9%	20.7%	20.7%	100%
Total	19.5%	43.9%	22%	14.6%	100%

Energy/electricity is introduced to students on the S-STEM with the following passage: "People invent, improve and maintain ways to make electricity or heat. They also design the electrical and other power systems in buildings and machines. This is energy/electricity work." Within the traditional group, 50% of students identified as (3) "interested" or (4) "very interested" in energy/electricity as a career, as compared to 47.6% of students assigned to the DBL group and 41.4% of students assigned to the scientific inquiry group (see Table 15).

Table 15. Energy/Electricity Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	25%	25%	34.4%	15.6%	100%
Design-Based Learning, *n*=21	14.3%	38.1%	28.6%	19%	100%
Scientific Inquiry, *n*=29	31%	27.6%	34.5%	6.9%	100%
Total	24.4%	29.3%	32.9%	13.4%	100%

Engineering is introduced to students on the S-STEM with the following passage: "People use science, math and computers to build different products (everything from airplanes to toothbrushes). Engineers make new products and keep them working." As seen in table 16, the traditional group participants were nearly twice as likely to select (1) "not at all interested" in engineering over the design-based learning group. The DBL group is also more than twice as likely to be (4)"very interested" in engineering as compared to the traditional group, and four times as likely when compared to scientific inquiry participants. Within the traditional group, 59.4% of students identified as (3) "interested" or (4) "very interested" in engineering as a career, as compared to 76.2% of students assigned to the DBL group and 58.6% of students assigned to the scientific inquiry group (see Table 16).

Table 16. Engineering Values

	Not at all interested	Not so interested	Interested	Very Interested	Total
Traditional, *n*=32	9.4%	31.3%	34.4%	25%	100%
Design-Based Learning, *n*=21	4.8%	19%	23.8%	52.4%	100%
Scientific Inquiry, *n*=29	17.2%	24.1%	44.8%	13.8%	100%
Total	11%	25.6%	35.4%	28%	100%

Discussion

Although there were identifiable differences noted in the crosstabulations of multiple career areas when using the scientific inquiry or design-based learning treatments, these differences were not significant at the .05 α level for any ANOVAs outside of the engineering career area. This is not unexpected; given the short time frame of the unit (nine days) and a lack of intentional focus on the majority of those career areas. This aligns with existing literature which shows exposure over time is a key variable for increasing student STEM efficacy and positive progression in STEM attitudes (e.g., Ernst, et. al, 2012); it's logical that exposure over time will render different results for career interest as well.

Of the 12 career areas identified on the S-STEM, three were intentionally discussed in a classroom: environmental work, chemistry, and engineering. The amount of time spent discussing career connections was minimal in each group, less than 10 minutes total in each classroom. The career area of environmental work was discussed on two occasions in the scientific inquiry classrooms and once within the design-based learning classrooms; these conversations appear to have made a difference, as students in both groups were less than half as likely to be "not at all interested" in environmental work as compared to the traditional group. Chemistry as a career path was discussed in the scientific inquiry classroom as part of their science experiment, which involved evaluating water filters effects on water pH; students in the scientific inquiry were most likely to show an interest in chemistry (41.4% of the group) (see Table 14). While most of these differences are not statistically significant, they ahold practical importance because of the implication that students career interest may be affected by career discussions aligned with the work they are doing.

As mentioned in the results section, the ANOVA for the engineering career area was statistically significant, $F(2, 79) = 3.281$, $p < .05$. While the Tukey post hoc analysis revealed that the mean increase from the traditional to design-based learning group was not statistically significant, given the similarities between the traditional and scientific inquiry scores, it is likely due to the lower *n* of the DBL group and it has the potential to yield different results with increased exposure. The engineering career area was mentioned within classrooms assigned to the design-based learning group on seven of the nine days; students in this group were half as likely to be “not at all interested” in engineering when compared to the traditional group (engineering=4.8% and traditional=9.4%, respectively) and twice as likely to be “very interested” (engineering=25% and traditional=52.4%, respectively) (see Table 16). Given that the engineering career area is the only one that had a statistically significant ANOVA, it could be postulated that it was the recurring connection between the students’ work and the career area made a difference.

The most visible differences appear when you compare the two experimental groups reported interests. Those in the scientific inquiry group participated in an active learning unit that made connections to chemistry, where students were twice as likely to rate their career interest as (4) “very interested” as compared to the design-based learning group. Similarly, the DBL group was almost four times as likely to rate their career interest as (4) “very interested” as compared to the scientific inquiry group within the engineering career area. This could be because at this age students are narrowing their interests based on the experiences they have and that as they select one interest, they begin to disregard options they know less about. This aligns with both theory (Super, 1957, 1990) and research (Watson & McMahon, 2005).

Also of interest is that the quantity of connections seems to correlate to the significance of the differences between groups; this infers that the more explicit career connections you make to hands-on work, the more likely it is to make a difference. Watson and McMahon (2005) discuss the recursive nature of children's career progression, so it makes sense that repetition is important. This aligns and builds on existing research; Parker & Jarolimek (1997) found that when young people map out their futures, they tend to choose professions that are familiar. Repetition of the career connection can build familiarity; research shows career awareness is the first step (Skolnik, 1995).

In terms of model adoption for the Radford school system, a merged pedagogical set with an emphasis on active learning opportunities and embedded career connections is being recommended based on these results. Based on these results, this model will provide students with the best opportunity to increase STEM career interest while building self-efficacy levels that can sustain them through their high school careers.

Limitations and Suggestions for Future Research

This study is based on several assumptions: first, that all students honestly answered the survey questions; second that quality of career connections is not as important as quantity, and finally that the S-STEM career area definitions would not create bias toward or against the career areas. If any of these assumptions turns out to be incorrect, the results could be impacted. There are other notable limitations with this study. For instance, this study has a relatively small sample size specific to one area of rural Appalachia; as such, the results are not necessarily generalizable to all Appalachian regions (or other rural areas). Although there were no statistical differences in the collected student demographic characteristics, it is unknown whether differences in variables that have shown to be statistically significant in other research but not measured in this study (e.g., parents' education level, parents' working in a STEM field, previous or concurrent participation in programs that could increase STEM career interest, etc.) could be effecting outcomes. It is recommended that similar studies be carried out in different regions to see if the results are generalizable. Follow-up studies concerning the quantity of connections made in each type of curriculum treatment are also recommended. Finally, a longitudinal study that examines the length of time or number of units required for overall STEM career interest increase a statistically significant amount would be another recommendation.

General Conclusions

Career development is a complex process, and the decisions young students' make rely on processing a wide range of information from many sources. Even looking at just a small portion of this process, career interest, relies on a large number of variables and interactions. The main aim of this research was to identify differences in career interest when active learning alternatives with embedded career connections are compared to traditional classroom methods. The answer found is, unsurprisingly, that it's complicated. Within this study, there is not a statistical difference in overall STEM career interest, or for most individual careers, when scientific inquiry or design-based learning is used in place of a traditional science unit. However, there is a pattern of increased scores when a career area is addressed during an active learning unit that could become significant if given more time or a larger *n.*

A systematic integration of career-related concepts throughout signature pedagogy based curricula and across content silos that is consistent with best practices is recommended for this age group. Treatments, like those described in this study (active learning opportunities with embedded career connections) should be integrated throughout a child's learning career, with explicit connections being drawn to the work they're doing to make a significant impact on their career interest. Ultimately, exposure to a variety of signature pedagogies that connect students to an assortment of career areas via embedded career connections will help students make informed decisions regarding their career path.

References

Adair, J. G. (1984). The Hawthorne effect: A reconsideration of the methodological artifact. *Journal of Applied Psychology*, 69(2), 334.

Ali, S. R., & Saunders, J. L. (2006). College expectations of rural Appalachian youth: An exploration of social cognitive career theory factors. Career Development Quarterly, 55, 38-51.

Ali, S., & Saunders, J. L. (2009). The career aspirations of rural Appalachian high school students. *Journal of Career Assessment,* 17(2), 172-188.

Appalachian Regional Commission. (2010). Socioeconomic overview of Appalachia, 2010. *Washington, DC: Appalachian Regional Commission*.

Armenti Jr, A., & Wheeler, G. F. (1978). Hawthorne effect and quality teaching: Training graduate teaching assistants to teach. *American Journal of Physics*, 46(2), 121-124.

Beale, A. V. (2000). Elementary school career awareness: A visit to a hospital. *Journal of Career Development*, 27(1), 65-72.

Beale, A. V. (2003). It takes a team to run a restaurant: Introducing elementary students to the interrelatedness of occupations. *Journal of Career Development*, 29, 211–220.

Borgen, W. A., & Young, R. A. (1982). Career perceptions of children and adolescents. *Journal of Vocational Behavior*, *21*(1), 37-49.

Brathwaite, A. D. (2002). A way with words: A unique approach to literacy and career development. *Journal of Career Development*, 28, 221–225.

Capobianco, B. M., Diefes-dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education*, *100*(2), 304-328.

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: A case study of design-based learning in a science context. *Journal of Technology Education*, 19(2), 22-39.

Dorr, A., & Lesser, G. S. (1980). Career awareness in young children. *Communication Research and Broadcasting*, 1(3), 36–75.

Duschl, R. (2007, September 1). Taking Science to School. Retrieved June 12, 2017, from http://books.nap.edu/catalog.php?record_id=11625#toc

Ernst, J. V., & Bottomley, L., & Parry, E. A. (2012, June), Term Analysis of an Elementary Engineering Design Approach Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. https://peer.asee.org/22030

Ernst, J. V., & Bottomley, L., & Parry, E. A., & Lavelle, J. P. (2011, June). Elementary Engineering Implementation and Student Learning Outcomes Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. https://peer.asee.org/17831

Estrin, E.T. (2002). Alternative assessment: Issues in language, culture, and equity, http://www.enc.org.

Friday Institute for Educational Innovation (2012). Student Attitudes toward STEM Survey – Upper Elementary School Students, Raleigh, NC: Author.

Gaito, J. (1980). Measurement scales and statistics: Resurgence of an old misconception.

Gleason, B. L., Peeters, M. J., Resman-Targoff, B. H., Karr, S., McBane, S., Kelley, K., & Denetclaw, T. H. (2011). An active-learning strategies primer for achieving ability-based educational outcomes. *American Journal of Pharmaceutical Education, 75*(9), 1.

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. *Journal of Vocational Behavior*, 66, 385–419.

Horton, P. B., McConney, A. A., Woods, A. L., Barry, K., Krout, H. L., & Doyle, B. K. (1993). A content analysis of research published in the Journal of Research in Science Teaching from 1985 through 1989. *Journal of Research in Science Teaching*, *30*(8), 857-869.

Howard, K. A., & Walsh, M. E. (2011). Children's conceptions of career choice and attainment: Model development. *Journal of Career Development*, *38*(3), 256-271.

Howard, K. A., Flanagan, S., Castine, E., & Walsh, M. E. (2015). Perceived influences on the career choices of children and youth: an exploratory study. *International Journal for Educational and Vocational Guidance*, 15(2), 99-111.

Jonassen, D. (1991). Objectivism vs constructivism: Do we need a new philosophical paradigm? *Educational Technology, Research and Development*, 39(3), 5-13.

Levine, T.R. & Hullett, C.R. (2002). Eta Squared, Partial Eta Squared and the Misreporting of Effect Size in Communication Research. Human Communication Research, 28, 612-625.

McMahon, M., & Patton, W. (1997). Gender differences in children and adolescents' perceptions of influences on their career development. *School Counselor*, 44, 368–376.

National Assessment of Educational Progress (2015). *2014-2015 The Condition of Education*. Retrieved from http://www.nationsreportcard.gov/science-2015/g8-state.aspx.

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

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in health sciences education*, *15*(5), 625-632.

Office of Science and Technology Policy (2013). Federal science, technology, engineering, and mathematics (STEM) education 5-year strategic plan. *National Science and Technology Council: Committee on STEM Education.*

Organization for Economic Co-operation and Development (2016). *PISA 2015 PISA Results in focus*. 'Washington, DC: OECD. Retrieved from: https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

PBS Kids. (n.d.). Introducing the design process. Retrieved from http:// www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_TG_DesignProcess.pdf

Phipps, B. J. (1995). Career dreams of preadolescent students. *Journal of Career Development*, 22, 19–32.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93 (3), 223-231

Rural School Community Trust. (2003, February). Why rural matters again: New report on the continuing need for every state to take action on rural education. *Rural Policy Matters*, 5, 1-5.

Schmitt-Wilson, S., & Welsh, M. (2012). Vocational knowledge in rural children: A study of individual differences and predictors of occupational aspirations and expectations. *Learning and Individual Differences*, 22, 862–867.

Schultheiss, D. E. P. (2008). Current status and future agenda for the theory, research, and practice of childhood career development. *The Career Development Quarterly*, 57(1), 7-24.

Skolnik, R. (1995). Doctor, lawyer... Technical chief? *Vocational Education Journal*, 70, 36–37, 55.

Spohn, K., Crowther, T., & Lykins, C. D. (1992). Appalachian access and success: A research project of the Ohio Board of Regents and a consortium of two- and four-year colleges and universities in Appalachian Ohio. Portsmouth, OH: Shawnee State University.

Super, D. E. (1957). The psychology of careers. New York: Harper.

Super, D.E. (1990). A life-span, life-space approach to career development. In D. Brown, L. Brooks, & Associates (Eds.), Career choice and development (2nd ed., pp. 197-261). San Francisco: Jossey-Bass.

Tamir, P. (1991). Practical work in school science: An analysis of current practice. In B. Woolnough (Ed.), Practical science (pp. 14-20). Buckingham: Open University Press

Tang, M., & Russ, K. (2007). Understanding and Facilitating Career Development of People of Appalachian Culture: An Integrated Approach. [Article]. Career Development Quarterly, 56(1), 34-46.

Tieken, M. (2014). *Why rural schools matter*. Chapel Hill, NC: The University of North Carolina Press.

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics*, 90, 403-418.

Trice, A. D., & Rush, K. (1995). Sex-stereotyping in four-year-olds' occupational aspirations. *Perceptual and Motor Skills*, 81, 701-702.

Trice, A. D., Hughes, M. A., Odom, C., Woods, K., & McClellan, N. C. (1995). The origins of children's career aspirations: IV. Testing hypotheses from four theories. *The Career Development Quarterly*, 43, 307–322.

U.S. Census Bureau. (2011). *Factfinder*, Retrieved from http://factfinder.census.gov

U.S. Census Bureau. (2014). *Factfinder*, Retrieved from http://factfinder.census.gov

Uden, L. & Beaumont, C. (2006). Technology and problem-based learning. London, UK: Information Science Publishing

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622-639.

Watson, M., & McMahon, M. (2005). Children's career development: A research review from a learning perspective. *Journal of Vocational Behavior*, 67, 119–132.

CHAPTER 4: MANUSCRIPT 2 USING DESIGN-BASED LEARNING TO INCREASE STEM ATTITUDES AND INTEREST IN STEM CAREERS

Abstract

"[T]oo many children prematurely exclude STEM-related study and work options, based on negative images of the field or negative ability beliefs" (van Tuijl & van der Molen, 2016, p. 159). To combat this process, positive supports are needed to scaffold students' STEM attitudes early in their academic careers. This research examined the effect of a design-based learning curriculum treatment implementation for a single unit on Radford City Schools fifth-grade students' STEM attitudes and interest in STEM careers through a pre/post design. The study showed statistically significant growth in overall STEM attitudes and within the science subtest specifically. Career interest in the general field of science showed significant increase, while change of interest in specific career areas was not statistically significant.

Introduction

Recent national reports have called for a change in science, technology, engineering, and math (STEM) teaching practices, calling for an emphasis on the integration between the STEM disciplines (National Research Council, 2009, 2011, 2012, 2014). STEM education, the "four allied fields of science, technology, engineering, and mathematics" (Sneider, 2011), should not be treated as "silos." Instead, engineering can serve as a motivating context to integrate the four disciplines (Katehi, Pearson, & Feder, 2009). While a relatively new area of research, results indicate that by contextualizing math and science content engineering experiences can enhance students' motivation and increase their problem-solving ability and achievement (Brophy, Klein, Portsmore, & Rogers, 2008; English & King, 2015; Stohlmann, Moore, & Roehrig, 2012).

One way to integrate engineering into STEM education is through Design-based learning (DBL), a teaching method that provides a natural and meaningful venue for learning both science and design skills through design project (Kolodner, 2002). DBL "enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their preference, learning styles, and various skills" (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008). It is an active learning process and as such, a teacher's role is no longer that of lecturer, instead their roles become that of tutor, guide, and partner in the learning process (Prince, 2004). DBL is typically team-based, and therefore collaborative in nature; students that engage in cooperative learning gain success in academic and non-academic achievements (Lazarowitz, Hertz-Lazarowitz & Baird, 1994, Verner & Hershko, 2003), and show gains in their interpersonal communication skills, presentation skills, and problem solving skills (Butcher, Stefanai & Tariq, 1995; Doppelt, 2004 ; Doppelt, 2006). Students are motivated to learn using DBL strategies because of the more explicit connection between their knowledge and real-life situations thanks to the design's purpose of meeting current and real needs (Doppelt, 2003; Hill & Smith, 1998). Increased engagement can lead to more positive attitudes toward STEM and/or increased interest in STEM careers.

Attitudes Toward STEM

STEM attitudes are a combination of self-efficacy and expectancy-value beliefs towards science, technology, engineering, and mathematics (Unfried, Faber, Stanhope, & Wiebe, 2015). When students have a positive attitude towards STEM by middle school, they are more likely to persist in pursuing a career in STEM (Tai, Lui, Maltese, & Fan, 2006). More exposure to STEM activities and opportunities have a long-term effect on attitudes (Mohr-Schroeder, Jackson, Miller, Walcott, Little et al., 2014). By incorporating effective curriculum treatments early and often, students will have better attitudes toward STEM.

Career Development and Interest

Self-efficacy regarding career interests is continuously revised as new input is provided. It is most fluid up until late adolescence/early adulthood, where those interests tend to stabilize; after which, new experiences do very little to change a person's career interests (Lent, Brown, & Hackett, 1994; Hansen, 1994). This is why it is crucial for students to have a variety of successful STEM experiences early on to draw from. Career interest is a complex concept that has many variables that play a role in its formation, including when to use an intervention and how to make it most effective.

Career interventions are most effective in elementary or middle school, (Legum & Hoare, 2004). In 2001, research by Pell and Jarvis indicated that the decline in interest in science and technology may begin as early as the last two years of elementary school. This is echoed by Archer and his team who reported that "young children have positive attitudes in science at age 10, yet this interest declines sharply as students' progress from one grade level to the next" (2010, p.629). This correlates with what research studies of undergraduate student experiences in choosing STEM professions have noted; the elementary years are the best time to create a connection, awareness, and interest in STEM fields (Russell, Hancock & McCullogh, 2007). These findings are in alignment with theory in the area of career development (Super, 1957, 1990), as well.

Theory informs us that career-related concepts and attitudes are first formed in childhood (e.g., Super, 1957; Gottfredson, 1981); how and when in childhood student career choice develops is less consistent and more complex in the literature. As van Tuijl and van der Molen

(2016) recommend, focusing on younger students broadens from career choice (something that typically occur at an older age) to career development (which happens at both younger and older ages). Super (1957, 1990) viewed career development as unfolding across the lifespan. Super's model begins with the Growth stage, which consists of three sub-stages: Fantasy (4-10 years) where role-playing is important, but needs dominate; Interest (11-12 years) where preferences are the major source of activities and aspirations; and Capacity (13-14 years) where the child considers abilities, training, and job requirements (Schultheiss, 2008). Within the Growth stage, children progress through four career development tasks: concern about the future, increasing personal control over self, developing an awareness of the importance of achieving in school and work, and acquiring competent work habits/ attitudes (Super, Savickas, & Super, 1996). Understanding where students are in the Growth stage is important when designing an intervention. For instance, that fifth graders are entering the interest sub-stage is important to note; positive interactions that create a preference for types of activities will have an effect on their career interest.

van Tuijl & van der Molen's (2016) overview and integration of the research on the children's career choice that is STEM-specific, finding that the literature points to three critical interrelated factors when it comes to children's (8–16 years) career development: knowledge; affective value; and ability beliefs and self-efficacy building. They argue that "knowledge of the STEM field, and of the self in STEM activities, and parents' and teachers' knowledge of the early circumscription processes of children aged 8–16 needs to be broadened" (p.174). Van Tuijl & van der Molen (2016) echo Hartung Porfeli, and Vondracek (2005), pointing out that young adults' career decisions are rooted in childhood, and also make the connection that while STEM content can be difficult and therefore not for everyone, "too many children prematurely exclude

STEM-related study and work options, based on negative images of the field or negative ability beliefs" (p. 159). To combat this process, we need to improve students' STEM attitudes early on and provide accurate images of the field, especially for disadvantaged students.

Research Questions

This research study was designed to investigate the impact of design-based learning on students' STEM attitudes and STEM career interest. It was guided by two research questions specific to student STEM efficacy and STEM career interest:

1. To what extent does design-based learning support an increase in students' attitudes regarding STEM subjects?
2. To what extent does design-based learning support an increase in students' interest in STEM careers?

This research examined the use of a design-based learning curriculum treatment implementation through a pre/post design. Differences in STEM attitudes and career interest were investigated through self-reported levels via a digital version of the Student-STEM survey.

Methodology

This study was conducted during a single two-week unit that 42 of the 126 fifth grade students in Radford City Schools participated in with the intent of measuring whether the DBL curriculum treatment had an effect on students STEM attitudes and/or interest in STEM careers. Existing literature has established that when there is a high level of self-efficacy in math and/or science, students are more inclined to pursue and persist in STEM degrees (Shoffner, Newsome, Barrio Minton, & Wachter Morris, 2015). Students are likely to persist when they are likely to succeed, meaning it has a high-expectancy value (Shoffner et al., 2015). One way attitudes towards STEM and interest in STEM careers can be measured is by the S-STEM Survey (Unfried et al., 2015), which this study used.

Participants

Radford City Schools serve approximately 1,600 students in grades PK-12. The community needs greater educational access and career awareness, especially for its economically disadvantaged students. An estimated 40 percent of Radford lives in poverty, nearly three times that of the state of Virginia as a whole. The city's median income is $30,284, less than half of the state's average, and a majority of the city lives just above that poverty line (U.S. Census Bureau, 2014). Within the school system, 53 percent of primary students are considered disadvantaged or living in poverty. Overall, 46 percent of the student body is considered Gap Group 1. One in three of the economically disadvantaged in the RCS class of 2016 didn't earn a regular high school diploma (Virginia Department of Education [VDOE], 2016). The students need quality educational models in place that work for this population. Fouad asserts that math and science-related skills may be beyond "remediation" upon high school entry and that career-related choices "must be addressed" before high school (1995). As fifth grade represents a critical juncture for students developmentally, this study focused its curriculum treatments there. Radford's fifth grade students all attend Belle Heth Elementary, a state-identified Title I focus school which means it's gap groups have one of the largest gaps to reach AMO. This study examined the effect of a design-based learning treatment for a single unit on Radford City Schools fifth-grade students' STEM attitudes and interest in STEM careers.

The fifth-grade population in Radford City Public Schools was recruited to participate in a series of STEM education studies, two of the six classrooms participated in this study. Radford is unique; it is a small city situated in rural Appalachia. Belle Heth Elementary, where all of the cities fifth graders attend, is a state-identified Title I focus school; 26% of students receive Title I services. The school has the following demographics: 75.6 percent white and 14.4 percent ethnic minority (black, Hispanic, Asian, American Indian, biracial, or multiracial); 11.3 percent have identified disabilities; and 49.5 percent are economically disadvantaged (VDOE, 2016). Each class included 21 students; of which 11 gave consent and had complete data.

Within the school district, an innovation team was created and tasked with examining curriculum, which this study informs. While classroom selection was random, the fifth grade was selected with input from innovation team members to begin examining curricula options.

Curriculum

The traditional unit pacing guide allotted nine days for the ecosystems unit; so, to keep in line with the other fifth grade classrooms, students in the two classrooms embarked on a 9-day ecosystems unit structured around design-based learning (see Table 1 for a day-by-day breakdown) that included the same number of instructional minutes as the traditional unit the school followed. Students' guided notes focused on building knowledge through connections, critical thinking, and diagramming. In addition to the double period for the design challenge on day 7, the activities for days 4 and 6 provided a chance for students to be introduced to the engineering design process while discussing the adaptations and niche of animals and insects in Virginia.

Table 1. Design-based learning ecosystems unit description

Day	Content	Actions
Day 1	none	No class held to provide time for a double-period on day 7
Day 2	populations, communities and ecosystems habitats and niches	Unit pre-test and survey Interactive video and notetaking in journals
Day 3	Structural and behavioral adaptations	Relevant science music played during review warm-up in journals Interactive video and notetaking
Day 4	Review animal adaptations, introduction of plant adaptations	Interactive video and notetaking Create-a-critter introduction to engineering design
Day 5	food webs	Hands-on introduction to food chain with cup-stacking activity as a team Build-a-bird review of adaptations. Notetaking in journals- emphasis diagramming
Day 6	food webs niche and life cycle	Relevant science music played during review warm-up in journals spider web design challenge- introduce the engineering design process to build and test a spider web that catches multiple-sized bugs.
Day 7	design challenge	Engineering Design Challenge (see Figure 1)
Day 8	review connect activity to human influence	Water filter discussion for warm-up Complete illustrations for human impact on the environment and relate the new information to the possible causes of the water issue from yesterday's experiment Interactive video
Day 9	unit and post-test	Unit test and survey

Figure 1 shows the design challenge posed for the day 4 mini-activity where students designed a rocky shore organism. On day 6 students engaged the engineering design process again when students were placed in design teams, provided a set of materials, and charged with building a prototype spider web that would best feed a spider; different sized insects were given different point values. Figure 2 shows sample artifacts from these activities.

Figure 1. Design Challenge from Day 4

Create-a-Critter

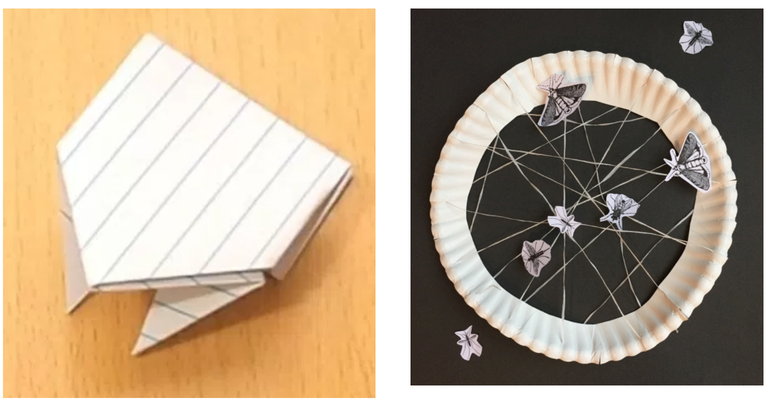
Problem: There aren't enough rock shore organisms surviving in your area anymore. So, you will be creating a rocky shore organism that can survive the challenges of the rocky shore, including the weight of the waves without burrowing into the sand.

How have others approached it: we'll share your research on local adaptations and make a chart on the next slide

Criteria and constraints: With your team, you will be creating your "critter" with only five index cards, scissors and tape. You will have 4 minutes to brainstorm and 11 minutes to build.

Figure 2. Applied Learning Activity Artifacts

DAY 4



DAY 6

Day 7 represented the culminating activity and artifact for the design-based learning unit. Students were provided 90 minutes to complete an engineering design challenge in which the town's environmental quality director is looking for a new groundwater filtration device to use in the water treatment facility. Students were charged with the following:

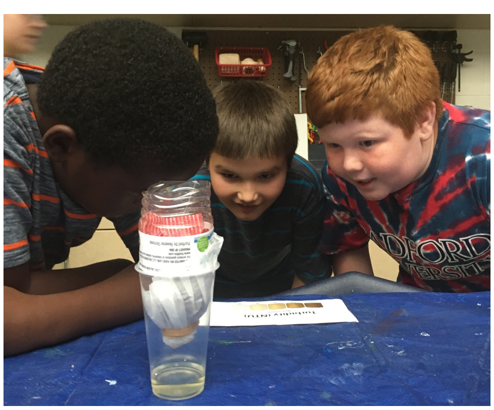
"Using the engineering design process, build and test and a filtration device. You must consider the materials and costs in your design. The treatment plant treats water for both animal consumption and human consumption. Each team will have access to the dirty water. There are two levels of filtration needed to supply the treatment facility. Before reaching the treatment facility, water for human consumption (‘A’ water) must have a turbidity level of <10 NTU. ‘B’ water for plant and animal use must have a turbidity level of <25 NTU. For each 10 ml of water that is filtered, your team will be credited $10 per ml if it meets the human standard, and $5 per ml if it meets the plant/animal standard” (see Appendix C).

Students were provided the following criteria and constraints:

- “Successful designs will filter water for A tank or B tank using only the materials available. Aim for the highest profit (total paid-costs of materials) possible within a 2-minute testing window.
- Tools may be used to alter the materials as necessary for the project.
- For water to be judged and purchased, a materials list and cost sheet for the final product must be provided.
- Filter prototypes must be ready for testing in 80 minutes.
- Unsafe behaviors will disqualify a team from continuing” (see Appendix C).

Figure 4 documents a design team testing one of their prototypes by measuring the water’s turbidity against the provided measurement tool. The design challenge was then connecting to the unit through a human influence requirement on day 8 before preparation for the unit test on the next day.

Figure 3. Testing during the Engineering Design Challenge



Procedures

The procedures for this study were approved by the University's human subjects review board. Letters explaining the study along with a copy of the informed consent document and a short demographic collection survey were sent home in the initial paperwork packet that goes home with each student at the start of the school year, approximately three weeks prior to administration of the measures. Students read and signed informed consent forms with their parents. The ecosystems unit took nine school days to complete, though day 1 the classes did not have any instruction. During the unit, these two classes used an abbreviated version of the traditional curriculum with an altered pacing guide that made space for the design challenge and two mini-activities. Unit Pre- and Post-testing was done using a traditional paper format; however, the survey instrument, Upper Elementary Student-STEM, responses were collected electronically using Google Forms at the start of the unit and again after the unit test was completed.

Instruments

School records provided student age, sex, race/ethnicity, IEP and 504 statuses, free/reduced-rate lunch status, gifted program status, as well as previous grades in math and science. A demographic collection survey was sent home to collect parent education level(s) (some grade school through finished graduate degree) and parent's field of work (converted to STEM or non-STEM).

The Upper Elementary School (4-5th) S-STEM Survey is an instrument designed to measure changes in students' confidence and efficacy in STEM subjects, 21st-century learning skills, and interest in STEM careers. Developed by the Friday Institute (Friday Institute for Educational Innovation, 2012), the S-STEM has four scales: science (9 items, 1 negatively worded), math (8 items, 3 negatively worded), engineering and technology (9 items), and 21st-century learning skills (11 items). Responses are provided on a Likert scale ranging from 1("strongly disagree") to 5 ("strongly agree"). Cronbach alphas of the subscales ranged from .86 and .89. Sample items for each subscale and Cronbach alphas obtained from this study are presented in Table 2. In the next section of the survey, students score their attitudes toward 12 STEM-based career areas using another Likert scale ranging from 1 ("not at all interested") to 4 ("very interested"), about their performance expectations for themselves in the next year ("not very well", "Ok/pretty well", or "very well"), and whether they know adults who work in the four STEM fields ("yes", "no", "not sure").

Table 2. S-STEM Survey Reliability for Subtests used

Construct	Number of Items	Cronbach's Alpha
Math Attitudes	8	.86
Science Attitudes	9	.84
Engineering and Technology Attitudes	9	.84

Results

Data was cleaned and compiled into SPSS, a statistical software package, for analysis. The study includes four dependent variables re-coded from raw responses to the Upper Elementary S-STEM: pre-post differences in the three compiled S-STEM subtest scores, a STEM efficacy composite score, and pre-post differences in the composite career interest score. A score was computed of students' responses to each question individually by assigning a numerical value to the ordinal responses, ranging from one to four. These scores were then calculated to form a single, collective score in each of the three efficacy subtests. Finally, the score differences were calculated between Pre- and Post-tests. Data were examined for data entry accuracy, missing values, and outliers. Of the 29 students with completed consent forms, 11 of the cases had complete data and were retained for the analyses. This low completion rate is due to technical difficulties experienced during the online survey.

Pre-post paired t-test analysis was conducted to evaluate the impact of the design-based learning treatment on efficacy in STEM subjects and career interest A paired t-test analysis with a population of 11 may seem small, but there is precedent in a number of studies and while de Winter (2013) finds the t-test feasible with extremely small *N*s (as low as 2) if the within-pair correlation is high, Slaton and Pawley (2015) even champions the "small N" in certain cases for STEM education research. The difference scores for math efficacy between the two groups were not normally distributed, as assessed by Shapiro-Wilk's test ($p = .033$). Given that math skills were not specifically targeted in the intervention and that the data does not meet the requirements of parametric testing, analysis is provided not examined. Within the engineering and technology efficacy data, one outlier was detected in that it was more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of this value did not reveal it to be extreme, so it was kept in the analysis.

STEM Attitudes

The first research question analyzed was: To what extent does design-based learning support an increase in students' attitudes regarding STEM subjects? All questions specifically related to science in the S-STEM survey's STEM attitude subtests were rated using a 5-point Likert scale where (1) "strongly disagree", (2) "disagree", (3) "neither agree nor disagree", (4) "agree", and (5) "strongly agree". Initial analysis of the data was an overall paired samples t-test for each STEM attitudes subtest and then a paired samples t-test for overall STEM attitudes was calculated. Table 1 details the results of the survey differences of attitudes toward STEM subjects. As seen in Table 3, the design-based learning treatment elicited an overall STEM attitudes mean increase of 8.91 points (SE = 3.72) over the course of the nine-day unit; this was a statistically significant increase, $t(10) = 2.398$, $p<.05$, with a medium effect size noted via Cohen's D ($d_z=.72$). DBL's influence on STEM attitudes in math ($M_d=3.36$, SE=1.76) was not significant at a .05 α ($p=.085$); it was statistically significant in science ($M_d=6.0$, SE=2.48, $p=.036$) with a medium effect size ($d_z=.73$); and there was a mean difference decrease of .73 on the engineering and technology subtest that was not statistically significant (SE=3.1, $p>.05$).

Table 3. Results from paired-sample t-tests for STEM Attitudes

Subject	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	p
Math	33.64	30.27	3.36	1.76	10	1.912	.085
Science	34.09	28.09	6.0	2.48	10	2.417	.036
Engineering & Technology	35.27	36	-.73	3.10	10	-.884	.819
Total STEM Attitudes	103	94.09	8.91	3.72	10	2.398	.037

Math Attitudes. The math attitudes subtest did not meet set criteria of the Shapiro-Wilk's test for normality (*p>.05)*. While there were changes in a positive direction on questions, a by-question analysis of this subtest revealed there were no statistically significant increases at a .05 α level for any of the eight individual subtest questions or the subtest itself (see Table 4).

Table 4. Pre- and Post-survey comparison: Math attitudes

Question	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	Sig. (2-tailed)
1. Math has been my worst subject.	4.36	3.64	.727	.488	10	1.491	.167
2. When I'm older, I might choose a job that uses math.	3.55	3.09	.455	.413	10	1.102	.296
3. Math is hard for me.	4.09	3.91	.182	.263	10	.690	.506
4. I am the type of student who does well in math.	4.27	3.64	.636	.338	10	1.884	.089
5. I can understand most subjects easily, but math is difficult for me.	3.91	3.55	.364	.472	10	.770	.459
6. In the future, I could do harder math problems.	4.55	4.0	.545	.282	10	1.936	.082
7. I can get good grades in math.	4.64	4.36	.273	.273	10	1.000	.341
8. I am good at math.	4.27	4.09	.182	.263	10	.690	.506
Subtest Total	33.64	30.27	3.36	1.76	10	1.912	.085

Note: questions 1, 3, and 5 were reverse coded to account for the wording.

Science Attitudes. As noted above, changes in the science attitudes subtest total were found to be statistically significant, $t(10) = 2.417$, $p<.05$ with a medium effect size (d_z=.73). There was statistically significant change in questions 10 "I might choose a career in science" (M_d=.818, SE=.296), $t(10) = 2.764$, $p<.05$, with a large effect (d_z=.83) ; 11 "After I finish high school, I will use science often."(M_d =1, SE=.302) , $t(10) = 3.317$, $p<.05$, with a large effect (d_z=1.0); 12 "When I am older, knowing science will help me earn money." (M_d =.82, SE=.325), $t(10) = 2.516$, $p<.05$, with a medium effect (d_z=.76); and 15 "Science will be important to me in my future career." (M_d =1.182, SE=.444), $t(10) = 2.665$, $p<.05$, with a large effect (d_z=.81). The score differences of the remaining questions were not found to statistically significant at the .05 α level (see Table 5).

Table 5. Pre- and Post-Survey Comparison: Science Attitudes

Question	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	Sig. (2-tailed)
9. I feel good about myself when I do science.	3.91	3.73	.182	.483	10	.377	.714
10. I might choose a career in science.	3.55	2.73	.818	.296	10	2.764	.020
11. After I finish high school, I will use science often.	3.55	2.55	1.000	.302	10	3.317	.008
12. When I am older, knowing science will help me earn money.	3.91	3.09	.818	.325	10	2.516	.031
13. When I am older, I will need to understand science for my job.	4.18	3.55	.636	.364	10	1.750	.111
14. I know I can do well in science.	4.0	3.45	.545	.562	10	.971	.355
15. Science will be important to me in my future career.	3.82	2.64	1.182	.444	10	2.665	.024
16. I can understand most subjects easily, but science is hard for me to understand.	3.27	3.27	.000	.447	10	.000	1.000
17. In the future, I could do harder science work.	3.91	3.18	.727	.488	10	1.491	.167
Subtest Total	34.09	28.09	6.0	2.48	10	2.417	.036

Note: question 16 was reverse coded to account for the wording.

Engineering & Technology Attitudes. Within the engineering and technology attitudes subtest, there were no statistically significant increases at a .05 α level for any of the nine individual subtest questions or the subtest itself (see Table 6).

Table 6. Pre- and Post-Survey Comparison: Engineering & Technology Attitudes

Question	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	p
18. I like to imagine making new products.	4.09	4.18	-.091	.392	10	-.232	.821
19. If I learn engineering, then I can improve things that people use every day.	3.91	3.91	.000	.357	10	.000	1.000
20. I am good at building or fixing things.	4.27	4.18	.091	.415	10	.219	.831
21. I am interested in what makes machines work.	4.09	4.0	.091	.513	10	.177	.863
22. Designing products or structures will be important in my future jobs.	3.55	3.55	.000	.467	10	.000	1.000
23. I am curious about how electronics work.	3.73	3.82	-.091	.456	10	-.199	.846
24. I want to be creative in my future jobs.	4.00	4.09	-.091	.343	10	-.265	.796
25. Knowing how to use math and science together will help me to invent useful things.	3.73	3.73	.000	.270	10	.000	1.000
26. I believe I can be successful in engineering.	3.91	4.27	-.364	.364	10	-1.000	.341
Subtest Total	35.27	36	-.73	3.10	10	-.884	.819

STEM Career Interest

The assumption of normality was not met for the areas of environmental work, medicine, earth science, computer science, chemistry, or engineering. The paired t-test conducted on the career interest subtest total was not significant ($p>.05$) (see Table 7); an analysis by career area is examined as well, with no statistically significant increases at a .05 α level for any of the 12 career areas the S-STEM collects responses on (see Table 8).

Table 7. Pre- and Post-Survey Comparison: Career Interest Overview

Subject	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	p
Overall Career Interest	30.27	29.18	1.09	1.80	10	.606	.558

Table 8. Pre- and Post-Survey Comparison: Career Interest by Career field

Subject	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	p
Physics	2.45	2.09	.364	.411	10	.886	.397
Environmental Work	2.18	2.45	-.273	.273	10	-1.00	.341
Biology	2.64	2.27	.364	.453	10	.803	.441
Veterinary Work	2.36	2.27	.091	.415	10	.219	.831
Mathematics	2.82	2.64	.182	.423	10	.430	.676
Medicine	2.0	2.09	-.091	.211	10	-.430	.676
Earth Science	2.36	2.27	.091	.163	10	.559	.588
Computer Science	2.82	2.73	.091	.251	10	.363	.724
Medical Science	2.27	2.36	-.091	.285	10	-.319	.756
Chemistry	2.18	2.27	-.091	.343	10	-.265	.796
Energy/Electricity	2.82	2.45	.364	.310	10	1.174	.267
Engineering	3.36	3.27	.091	.315	10	.289	.779
Overall Career Interest	30.27	29.18	1.09	1.80	10	.606	.558

Several STEM attitudes questions address jobs and careers more broadly. A paired sample t-test was conducted on each question that addressed the students' interest in a job or career; this included one math question, three science questions, and two engineering and technology questions (see Table 9). In question 10, students were asked to score the statement, "I might choose a career in science."; the difference in Pre- and Post-survey responses was statistically significant, $t(10)=2.764$, $p<.05$. Also significant was the difference for question 15, "Science will be important to me in my future career, $t(10)=2.665$, $p<.05$. The remaining questions were not statistically significant at the .05 α level.

Table 9. Subtest questions regarding career interest, Pre- and Post-Survey Comparison

Subject	Post-test Mean	Pre-test Mean	Mean Difference	SE	df	t	p
Math							
q2. When I'm older, I might choose a job that uses math.	3.55	3.09	.455	.413	10	1.102	.296
Science							
q10. I might choose a career in science.	3.55	2.73	.818	.296	10	2.764	.020
q13. When I am older, I will need to understand science for my job.	4.18	3.55	.636	.364	10	1.750	.111
q15. Science will be important to me in my future career.	3.82	2.64	1.182	.444	10	2.665	.024
Engineering & Technology							
q22. Designing products or structures will be important in my future jobs.	3.55	3.55	.000	.467	10	.000	1.000
q24. I want to be creative in my future jobs.	4.0	4.09	-.091	.343	10	-.265	.796

Discussion

While this study has a small sample (*n*=11), there is both precedent and the statistically significant analyses show medium and large effect sizes, which tell us the findings have value in the field and are worth exploring further. Regarding the lack of significance in the defined career areas and within the engineering and technology attitudes subtest, repeated exposure over time may render different results; I would expect to see a positive progression in engineering and technology attitudes, especially as the curricula content diversified. As for the S-STEM questions for engineering and technology attitudes, they focus on comfort or interest in specific engineering and technology content rather than process (e.g., q19 "things that people use every day", q21 "machines", q23 "electronics"), so it's possible that the lack of movement on these questions (MD= .00, MD=.091, MD=-.091) can be attributed to poor alignment with this unit's content. This lack of alignment is likely also the cause for a lack of movement in the identified career areas. Without an intentional focus on the career area, it's unlikely students' career interest would be changed from participation in the unit. This lack of results infers that intentional connections are necessary for change to occur.

Beliefs Regarding the Current and Future Self

The overall increase in STEM attitudes aligns with other research on integrating engineering design into the elementary classroom (e.g., Ernst, Bottomley, Parry, & Lavelle, 2011), since it includes self-efficacy questions as part of its attitudes measurement. Within the science subtest, there is a clear division of current self-efficacy beliefs (questions 9, 14, and 16) and those related to the future (10-13, 15, and 17). This divide is noticeable when looking at the mean differences as well (see Table 5). With regard to current self-efficacy, all three mean differences show little to no change; whereas there is major growth found in four of the six questions regarding the future. This polarizing response pattern tells us that students were engaged and are now interested in a future with science, but don't yet trust their abilities. Educational psychology tells us that time is necessary to change deep-held beliefs, it is likely that with repeated exposure to design-based learning opportunities, students' self-efficacy would rise like their interest has.

Career Interest

As noted above, the lack of direct association between the content and career areas defined in the S-STEM is likely the reason for a lack of change. Of more interest is the substantial increase in interest in the general field of science noted in questions 10 "I might choose a career in science" (MD=.818) and 15 "Science will be important to me in my future career." (MD=1.182). These sizeable jumps were not just significant, but have large effect sizes as well (d_z>.8). Design-based learning is a positive experience that invigorated student interest in science careers. At this age, students don't need to know exactly what career they will choose so long as they are not pre-maturely excluding STEM-related study and work options (Van Tuijl & van der Molen, 2016), and based on these improved STEM attitudes and career interest this treatment prevents pre-mature exclusion of science careers.

Limitations and Suggestions for Future Research

A small n was not planned for with this study, technology issues rendered nearly half the pre-tests un-submitted and eight post-tests were not collected due to the student only being available after participation in an enrichment day that included another science lesson that could have interfered with results. This small n could affect results in several ways- first, while normality is assumed based on the Shapiro-Wilk test results, with such a small data set it's impossible to be certain. It also affects the generalizability of the results. A third limitation is not knowing the effect of the self-reporting bias. Another possible limitation is the influence of previous or concurrent long-term, hand-on STEM experiences. Participants may already have positive attitudes during the pre-survey resulting in a flat or no- increase in STEM attitudes for the post-survey; future studies with a larger population could group students by their original pre-survey score in futures studies to account for bias. Additionally, as a cross-sectional study, this data gives us only a single attempt at the engineering design process. It would be meaningful to conduct a longitudinal study to measure students' change in their levels of self-efficacy and career interests over a series of units. Additional recommendations for future research include:

- Completing this study again for the whole grade or at multiple grade levels.
- Duplicating this study in other regions to see if results are generalizable.
- Using a larger population so that analysis on demographic subgroups (by gender, socioeconomic status, ethnicity, etc.) can be conducted as well.

Conclusion

This study shows that design-based learning is effective in increasing STEM attitudes and career interest on Radford's fifth grade students. As seen with previous research, DBL is an effective curriculum treatment to engage students in science content, and that engagement is affecting student beliefs. However, exposure over time is necessary, and a single unit is not sufficient to make sweeping changes to a students' deep-set beliefs regarding certain types of STEM attitudes. Nor is a single unit sufficient in providing an adequate amount of career awareness with which an informed decision can later be made. Students knowledge of potential careers is recursive, they need continuous feedback regarding available options and how their abilities and interests fit those options.

The findings from this research study could provide educational leaders and practitioners insight on how best to improve student outcomes for both short-term and long-term objectives that can benefit both the student and the region. Administrators have the ability to induce change on a larger scale, but this isn't exclusive to funding access. The model and issues discussed in this study (and others like it) have implications for the design, development, and evaluation of K-12 STEM workforce education programs. With access to this information, administrators can ensure that when setting conditions for student learning, career awareness and early workplace readiness skills are considered for elementary curriculum. They can alter existing PD to encourage and support strategies that develop students career awareness and early workplace readiness skills at the elementary level.

The overall results suggest that even a short-term unit can positively impact students' STEM self-efficacy and interest in STEM careers, but more research is needed on the design-based learning treatment with a larger population. Future research is planned to more finely examine design-based learnings effect on STEM attitudes and STEM career interest.

References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). “Doing” science versus “being” a scientist: Examining 10/11-year-old schoolchildren’s constructions of science through the lens of identity. Science Education, 94, 617-639. doi:10.1002/sce.20399

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. Journal of Engineering Education, 97(3), 369–387. http://dx.doi.org/10.1002/j.2168-9830.2008.tb00985.x

Butcher, A.C. Stefanai, L. A. J. & Tariq V. N., (1995). Analysis of peer-, self-, and staff-assessment in group project work. Assessment in Education, 2 (2), 165-185.

De Winter, J. C. (2013). Using the Student's t-test with extremely small sample sizes. Practical Assessment, Research & Evaluation, 18(10).

Doppelt, Y. (2003). Implementing and assessing project-based learning in a flexible environment. The International Journal of Technology and Design Education, 13 (3), 255–272.

Doppelt, Y. (2004). Impact of science-technology learning environment characteristics on learning outcomes: Pupils' perceptions and gender differences. Learning Environments Research, 7 (3), 271–293.

Doppelt, Y. (2006). Teachers’ and pupils’ perceptions of science–technology learning environments, Learning Environment Research, 9 (2), 163-178

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: A case study of design-based learning in a science context. Journal of Technology Education, 19(2), 22-39.

English, L. D., & King, D.T. (2015). STEM learning through engineering design: fourth-grade students' investigations in aerospace. International Journal of STEM Education, 2(14), 1-18. Doi:10.1186/s40594-015-0027-7.

Fouad, N. A. (1995). Career linking: An intervention to promote math and science career awareness. Journal of Counseling & Development, 73(5), 527-534.

Hansen, J. C. (1994). The measurement of vocational interests. Personnel selection and classification, 293-316.

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. Journal of Vocational Behavior, 66, 385–419.

Hill, A. M. & Smith, H. A. (1998). Practice meets theory in technology education: A case of authentic learning in the high school setting. Journal of Technology Education, 9(2), 29-45.

Katehi, L., Pearson, G., & Feder, M. (2009). Engineering in K-12 education: Understanding the status and improving the prospects. Washington, DC: National Academies Press.

Kolodner, J. L. (2002). Facilitating the learning of design practices: Lessons learned from an inquiry into science education. Journal of Industrial Teacher Education, 39(3).

Lazarowitz, R., Hertz-Lazarowitz, R., & Baird J. H. (1994). Learning in a cooperative setting: Academic achievement and affective outcomes. Journal of Research in Science Teaching, 31, 1121–1131.

Legum, H. L., & Hoare, C. H. (2004). Impact of a career intervention on at-risk middle school students' career maturity levels, academic achievement, and self-esteem. Professional School Counseling, 148-155.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unified social cognitive-theory of career and academic interest, choice, and performance [Monograph]. Journal of Vocational Behavior, 45, 79-122.

Levine, T.R. & Hullett, C.R. (2002). Eta Squared, Partial Eta Squared and the Misreporting of Effect Size in Communication Research. Human Communication Research, 28, 612-625.

Mohr-Schroeder, M. J., Jackson, C., Miller, M., Walcott, B., Little, D. L., Speler, L., ... & Schroeder, D. C. (2014). Developing middle school students' interests in STEM via summer learning experiences: See Blue STEM camp. School Science and Mathematics, 114(6), 291-301.

PBS Kids. (n.d.). Introducing the design process. Retrieved from http:// www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_TG_De signProcess.pdf

Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93 (3), 223-231

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. Science(Washington), 316(5824), 548-549.

Schultheiss, D. E. P. (2008). Current status and future agenda for the theory, research, and practice of childhood career development. The Career Development Quarterly, 57(1), 7-24.

Shoffner, M. F., Newsome, D., Barrio Minton, C. A., & Wachter Morris, C. A. (2015). A qualitative exploration of the STEM career-related outcome expectations of young adolescents. Journal of Career Development, 42(2), 102-116.

Slaton, A. E., & Pawley, A. L. (2015, June), The Power and Politics of STEM Research Design: Saving the "Small N" Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.2490

Sneider, C. (2011). A Possible Pathway for High School Science in a STEM World. Publications. Paper 159. http://digitalcommons.usu.edu/ncete_publications/159

Super, D. E. (1957). The psychology of careers. New York: Harper.

Super, D. E., Savickas, M. L., & Super, C. M. (1996). The life-span, life-space approach to careers. In D. Brown, L. Brooks, & Associates (Eds.), Career choice and development (3rd ed., pp. 121-178). San Francisco: Jossey-Bass.

Super, D.E. (1990). A life-span, life-space approach to career development. In D. Brown, L. Brooks, & Associates (Eds.), Career choice and development (2nd ed., pp. 197-261). San Francisco: Jossey-Bass.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. Life sci, 1, 0-2.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). Journal of Psychoeducational Assessment, 33(7), 622-639.

van Tuijl, C., & van der Molen, J. H. W. (2016). Study choice and career development in STEM fields: an overview and integration of the research. International journal of technology and design education, 26(2), 159-183.

Verner, M. I & Hershko, E. (2003). School graduation project in robot design: A case study of team learning experiences and outcomes. Journal of Technology Education, 14(2), 40–55.

Virginia Department of Education (2012). Governor's STEM academies. Retrieved from http://www.doe.virginia.gov/instruction/career_technical/gov_academies/index.shtml

Virginia Department of Education (2016). Radford School Quality Profile. Retrieved from http://schoolquality.virginia.gov/

Watson, M., & McMahon, M. (2005). Children’s career development: A research review from a learning perspective. Journal of Vocational Behavior, 67, 119–132.

Zhbanova, K.S., Rule, A.C., Montgomery, S.E. (2003). Defining the Difference: Comparing Integrated and Traditional Single-Subject Lessons. Early Childhood Education Journal, 38(4), 251–258. doi:10.1007/s10643-010-0405-1

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses conclusions and recommendations derived from the data analysis as presented in the two manuscripts and discussed concurrently with regard to future practice. This is followed by recommendations for application of these findings to research and practice.

Conclusions and Implications

It's understood that America's STEM pipeline will need to be increased and diversified in the coming years. This is an issue that the field of education is grappling with right now, especially regarding how to address the issue effectively in early grades education. Career choice is a complex and lengthy process. At the secondary level, Career and Technical Education (CTE) programs provide an opportunity for students to build college and career readiness skills while exploring career opportunities. However, research tells us this is often too late to make a difference when it comes to STEM education (Joyce & Farenga, 1999); it's known that by 10 years old, students rely on their own experiences to make decisions regarding their future career (Seligman et al.,1991).

At the high school level, there are direct connections between STEM and CTE by way of programs (e.g., FIRST Robotics or a trade and industrial program at the high school level) and courses (e.g., an industrial math class or cooperative opportunities in the STEM community) working to engage students in STEM career pathways. CTE initiatives contributing to the advancement of STEM education are readily available at this level, such as the Virginia Governor's STEM Academies. The academies were designed to increase STEM literacy and other critical skills, knowledge, and credentials that are needed for high-demand and high-wage, and high-skilled careers (VDOE, 2012). For an example at the national level, the National Center for Research in Career and Technical Education's (NCRCTE) Math-in-CTE-based program is an effective program. The problem with these programs is that they're coming too late to reach many students; students are disengaging with STEM content much earlier than when these programs are available in K-12 education. As such, additional interventions need to occur earlier to make a difference for all students.

By focusing applied experiences and career awareness efforts in elementary school that have a similar structure to the already successful secondary models, students are provided the opportunity to make informed choices by exploring the skills required of different careers as well as their interests before "too many children prematurely exclude STEM-related study and work options" (Van Tuijl & van der Molen, 2016, p. 159). What we can glean from secondary programs such as those described above is that when CTE is merged with STEM career awareness initiatives, there are increases to both a students' understanding of STEM content and interest in STEM career pathways (Hyslop, 2010). These two manuscripts support the effort to bridge CTE principles into elementary STEM education efforts by serving as a starting point for how to bring the combination of CTE principles and STEM education into elementary education in a developmentally appropriate way.

The first manuscript, *Building STEM Career Interest Through Curriculum Treatments*, presents a study that examined the impacts of design-based learning and scientific inquiry curriculum treatments with embedded career content on the career interest of fifth-grade students as compared to traditional classroom methods. Results show a statistically significant increase to interest in engineering as a career when design-based learning is used in the classroom. There is also an upward trend noted in students' STEM career interests when the curriculum treatments are used in several other career areas as well. This trend is not yet statistically significant for most career areas, but according to literature (e.g., Ernst, et al., 2012), exposure over time will likely also yield a different result.

Using a pre/post study design the second manuscript, *Using Design-Based Learning to Increase STEM Attitudes and Interest in STEM Careers*, examines the effect design-based learning has on Radford students' STEM attitudes and career interest. There were identifiable differences on several science attitudes questions, three with large effect sizes (d_z>.8). There was an identifiable difference in the overall STEM attitudes of the students with a medium effect size (d_z>.6). Within the science attitudes subtest, scores were polarized from differences of 0 to over 1 point (on a 5-point scale); this divide occurs between questions regarding current self-efficacy beliefs (low score differences) and those related to the future (high score differences). This polarizing response pattern tells us that students were engaged and are now interested in a future with science, but don't yet trust their abilities. Within the identified career areas, there was no statistically significant growth. However, when looked at more generally, there were identifiable differences on students' consideration of careers in the field of science, with a large effect size (d_z>.8).

Collectively, these studies suggest that from a career interest perspective, STEM education benefits from active learning opportunities such as design-based learning and scientific inquiry. This research serves as a foundation for the effectiveness of having career awareness and career exposure opportunities built into active learning instruction, which does not occur currently. Built on secondary CTE principles, but at a level appropriate for elementary students, using active learning opportunities with embedded career connections has the potential to be an effective solution to students' premature exclusion of STEM-related study and work options identified in the literature. Through preliminary exposure to this unique combination at the elementary level, a stronger foundation can be built for both ability and interest in STEM.

Recommendations

For Practice

This dissertation connects to a more substantial body of research that shows exposure to active learning opportunities over time is necessary for meaningful change; a single unit is not sufficient to make sweeping changes to a students' deep-set beliefs regarding certain types of STEM attitudes or in positively affecting their career development. It builds on that knowledge by suggesting embedded career connections and that these interventions occur during the elementary years to provide a foundation of STEM efficacy and interest before students begin exiting the STEM pipeline.

Knowing that students' knowledge of potential careers is recursive and that their attitudes and beliefs are constantly evolving, adoption as a whole-school model is recommended. Exposure to a variety of signature pedagogies that connect students to an assortment of career areas will help students make informed decisions regarding their career path. Traditional instruction lacks direct application of skills, and as such, should be used minimally. A finely-mixed pedagogical set with an emphasis on active learning opportunities and embedded career connections will provide students with the best opportunities to make informed career choices later while engaging them in the content now. Teachers should embed career awareness opportunities and career connections into hands-on curricula. In terms of model adoption for the Radford school system, based on these results, this model will provide students with the best opportunity to increase STEM career interest while building self-efficacy levels that can sustain them through their high school careers and beyond.

The following recommendations for classroom teachers, teacher educators and supervisors/administrators are also recommended:

- Professional development for formal educators in how to design and implement active learning opportunities with embedded career connections.
- Practitioners should integrate signature pedagogies into humanities coursework as well to provide students with more authentic learning experiences to draw from.

For Research

Just as design-based learning has shown effective for improving reported career interest in engineering, additional signature pedagogies should be identified and tested for inclusion in pedagogical sets that can affect change in other STEM career areas. Further research should be conducted studying the use of active learning opportunities with embedded career connections on larger populations, in different regions, and with a variety of demographics and grade levels to see if the results are generalizable. And given the implications of merging CTE principles into elementary STEM education, follow-up research that measures changes in introductory workplace readiness skills, such as P21's 4Cs, would be prudent to help situate elementary education as a precursor to CTE workplace readiness skills. The following studies are also recommended:

- A Chi-square analysis to examine the relationship between the quantity of career connections identified in a unit and reported career interest.
- A longitudinal study that examines the length of time or number of units required for overall STEM career interest increase a statistically significant amount would be another recommendation.

- A Multiple Regression Analysis (MRA) to create a parsimonious model of STEM career interest.

References

Adair, J. G. (1984). The Hawthorne effect: A reconsideration of the methodological artifact. *Journal of Applied Psychology*, 69(2), 334.

Ali, S. R., & Saunders, J. L. (2006). College expectations of rural Appalachian youth: An exploration of social cognitive career theory factors. Career Development Quarterly, 55, 38-51.

Ali, S., & Saunders, J. L. (2009). The career aspirations of rural Appalachian high school students. *Journal of Career Assessment,* 17(2), 172-188.

Allen, E.E., & Lederman, L. (1998). Lessons Learned: The Teachers Academy for Mathematics and Science. *The Phi delta* Kappan, 80, pp. 158-164.

American Association for the Advancement of Science (1989). *Science for All Americans*. Washington, DC: Author

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (2000). Proceedings of the AAAS Technology Education Research Conference. Washington, DC: Author. Retrieve from www.project2061.org/technology

American Association of University Women. (1998). Gender gaps: where our schools fail our children. Washington, DC: AAUW Educational Foundation.

Appalachian Regional Commission. (2010). Socioeconomic overview of Appalachia, 2010. *Washington, DC: Appalachian Regional Commission*.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). “Doing” science versus “being” a scientist: Examining 10/11-year-old schoolchildren’s constructions of science through the lens of identity. *Science Education*, 94, 617-639. doi:10.1002/sce.20399

Armenti Jr, A., & Wheeler, G. F. (1978). Hawthorne effect and quality teaching: Training graduate teaching assistants to teach. *American Journal of Physics*, 46(2), 121-124.

Association for Career and Technical Education (2014). ACTE: Voices support for Pathways to Prosperity Act of 2014. Retrieved from http://www.acteonline.org/general.aspx?id=6572#.U7BVVPldWSo

Association for Career and Technical Education (n.d.) College and Career Ready through CTE. Retrieved from https://www.acteonline.org/uploadedFiles/Assets_and_Documents/Global/files/Policy/ACTE-NRCCUA%20College%20and%20Career%20Ready%20Infographic.pdf

Auger, R. W., Blackhurst, A. E., & Wahl, K. H. (2005). The development of elementary-aged children’s career aspirations and expectations. *Professional School Counseling*, 8, 322–329.

Beale, A. V. (2000). Elementary school career awareness: A visit to a hospital. *Journal of Career Development*, 27(1), 65-72.

Beale, A. V. (2003). It takes a team to run a restaurant: Introducing elementary students to the interrelatedness of occupations. *Journal of Career Development*, 29, 211–220.

Bieber, A., P. Marchese, et al. (2005). "The Laser Academy: An After-School Program to Promote Interest in Technology Careers." *Journal of Science Education & Technology*, 8.

Bloch, D. P. (1996). Career development and workforce preparation: Educational policy versus school practice. *Career Development Quarterly*, 45, 20–40.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, 26(3-4), 369-398. Chicago.

Bonnstetter, R. J. (1998). Inquiry: Learning from the past with an eye on the future. *Electronic Journal of Science Education*, *3*(1), 130-136.

Borgen, W. A., & Young, R. A. (1982). Career perceptions of children and adolescents. *Journal of Vocational Behavior*, *21*(1), 37-49.

Brand, B., Valent, A., & Browning, A. (2013). How Career and Technical Education Can Help Students Be College and Career Ready: A Primer. *College and Career Readiness and Success Center.*

Bransford, J., Brown, A., & Cocking, R. (Eds.). (1999). How people learn: Brain, mind, experience, and school (Report of the National Research Council). Washington DC: National Academy Press

Brathwaite, A. D. (2002). A way with words: A unique approach to literacy and career development. *Journal of Career Development*, 28, 221–225.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3-11.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. Journal of Engineering Education, 97(3), 369–387. http://dx.doi.org/10.1002/j.2168-9830.2008.tb00985.

Brown, D. F. (2006). It's the curriculum, stupid: There's something wrong with it. *Phi Delta Kappan*, *87*(10), 777-783.

Butcher, A.C. Stefanai, L. A. J. & Tariq V. N., (1995). Analysis of peer-, self-, and staff-assessment in group project work. *Assessment in Education, 2* (2), 165-185.

Capobianco, B. M., Diefes-dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education*, *100*(2), 304-328.

Casey, R (2012). STEM education: preparing for the jobs of the future. U.S. Congress Joint Economic Committee, Washington, DC. As quoted in Reider, D., Knestis, K., & Malyn-Smith, J. (2016). Workforce Education Models for K-12 STEM Education Programs: Reflections on, and Implications for, the NSF ITEST Program. J*ournal of Science Education and Technology*, 25(6), 847-858.

Casner-Lotto, J., & Benner, M. W. (2006). Are They Ready to Work? Employers' Perceptions on the Basic Knowledge and Applied Skills of New Entrants to the 21st Century US Workforce. The Conference Board, Inc., Corporate Voices for Working Families, Partnership for 21st Century Skills, and Society for Human Resource Management.

Chang, C., & Mao, S. (1999). Comparison of Taiwan Science Students' Outcomes with Inquiry-Group versus Traditional Instruction. *The Journal of Educational Research,92*(6), 340-346. Retrieved from http://www.jstor.org.ezproxy.lib.vt.edu/stable/27542235

Cleaves, A. (2005). "The Formation of Science Choices in Secondary School." *International Journal of Science* Education 27(4): 471-486.

Colley, K. E. (2008). Project-based science instruction: A primer. *The Science Teacher*, 75(8), 23–28.

Colston, N., Thomas, J., Ley, M. T., Ivey, T., & Utley, J. (2017). Collaborating for Early-Age Career Awareness: A Comparison of Three Instructional Formats. *Journal of Engineering Education*, *106*(2), 326-344.

Coppes, M. (2016). *New opportunities for CTE in the every student succeeds act*. Alexandria: Association for Career and Technical Education.

Crockett, L., Jukes, I., & Churches, A. (2011). Literacy is not enough: 21st century fluencies for the digital age. Corwin Press.

de Jong, & van Joolingen, (1998). Scientific discovery learning with computer simulations of conceptual domains, *Review of Educational Research*, 68, pp. 179–202, http://dx.doi.org.ezproxy.lib.vt.edu/10.2307/1170753

De Winter, J. C. (2013). Using the Student's t-test with extremely small sample sizes. *Practical Assessment, Research & Evaluation*, *18*(10).

DeJarnette, N. K. (2012). America's children: Providing early exposure to stem (science, technology, engineering, and math) initiatives. *Education*, 133(1), 77-84.

Doppelt, Y. (2003). Implementing and assessing project-based learning in a flexible environment. *The International Journal of Technology and Design Education, 13* (3), 255–272.

Doppelt, Y. (2004). Impact of science-technology learning environment characteristics on learning outcomes: Pupils' perceptions and gender differences. *Learning Environments Research, 7* (3), 271–293.

Doppelt, Y. (2006). Teachers' and pupils' perceptions of science–technology learning environments, *Learning Environment Research, 9* (2), 163-178

Doppelt, Y., & Barak, M. (2002). Pupils identify key aspects and outcomes of a technological learning environment. *Journal of Technology Studies, 28* (1), 12–18.

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: A case study of design-based learning in a science context. *Journal of Technology Education*, 19(2), 22-39.

Dorr, A., & Lesser, G. S. (1980). Career awareness in young children. *Communication Research and Broadcasting*, 1(3), 36–75.

Dugger, W. E., Jr. (2010). Evolution of STEM in the United States. Retrieved from http://www.iteaconnect.org/Resources/PressRoom/AustraliaPaper.pdf

Duschl, R. (Ed.). (2007, September 1). Taking Science to School. Retrieved June 12, 2017, from http://books.nap.edu/catalog.php?record_id=11625#toc

English, L. D., & King, D.T. (2015). STEM learning through engineering design: fourth-grade students' investigations in aerospace. *International Journal of STEM Education,* 2(14), 1-18. Doi:10.1186/s40594-015-0027-7.

Ernst, J. V., & Bottomley, L., & Parry, E. A. (2012, June), Term Analysis of an Elementary Engineering Design Approach Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. https://peer.asee.org/22030

Ernst, J. V., & Bottomley, L., & Parry, E. A., & Lavelle, J. P. (2011, June), Elementary Engineering Implementation and Student Learning Outcomes Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. https://peer.asee.org/17831

Estrin, E.T. (2002). Alternative assessment: Issues in language, culture, and equity, http://www.enc.org.

Fouad, N. A. (1995). Career linking: An intervention to promote math and science career awareness. *Journal of Counseling & Development*, *73*(5), 527-534.

Friday Institute for Educational Innovation (2012). *Student Attitudes toward STEM Survey – Upper Elementary School Student*s, Raleigh, NC: Author.

Gaito, J. (1980). Measurement scales and statistics: Resurgence of an old misconception.

Glaeser, E. G. (2009). Education Last Century, and Economic Growth Today. *The New York Times*.

Gleason, B. L., Peeters, M. J., Resman-Targoff, B. H., Karr, S., McBane, S., Kelley, K., . . . Denetclaw, T. H. (2011). An active-learning strategies primer for achieving ability-based educational outcomes. *American Journal of Pharmaceutical Education, 75*(9), 1.

Gottfredson, L.S. (1981). Circumscription and compromise: A developmental theory of occupational aspirations [Monograph]. Journal of Counseling Psychology, 28, 545-579.

Grigg, J., Kelly, K. A., Gamoran, A., & Borman, G. D. (2013). Effects of two scientific inquiry professional development interventions on teaching practice. *Educational Evaluation and Policy Analysis*, *35*(1), 38-56.

Hansen, J. C. (1994). The measurement of vocational interests. *Personnel selection and classification*, 293-316.

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. *Journal of Vocational Behavior*, 66, 385–419.

Helwig, A. (1998). Occupational aspirations of a longitudinal sample from second to sixth grade. *Journal of Counseling and Development*, 24, 247–266.

Herr, E. L., Cramer, S. H., & Niles, S. G. (2004). *Career guidance and counseling through the lifespan: Systematic approaches* (6th ed.). Boston: Allyn & Bacon.

Hill, A. M. & Smith, H. A. (1998). Practice meets theory in technology education: A case of authentic learning in the high school setting. *Journal of Technology Education, 9*(2), 29-45.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academies Press.

Horton, P. B., McConney, A. A., Woods, A. L., Barry, K., Krout, H. L., & Doyle, B. K. (1993). A content analysis of research published in the Journal of Research in Science Teaching from 1985 through 1989. *Journal of Research in Science Teaching*, *30*(8), 857-869.

Howard, K. A., & Walsh, M. E. (2011). Children's conceptions of career choice and attainment: Model development. *Journal of Career Development*, *38*(3), 256-271.

Howard, K. A., Flanagan, S., Castine, E., & Walsh, M. E. (2015). Perceived influences on the career choices of children and youth: an exploratory study. *International Journal for Educational and Vocational Guidance*, 15(2), 99-111.

Hyslop, A. (2010). CTE's Role in Science, Technology, Engineering and Mathematics. *Techniques: Connecting Education and Careers (J1)*, *85*(3), 16-20.

International Technology Education Association. (2000). Standards for technological literacy: Content for the study of technology.

International Technology Education Association. (2002). Standards for technological literacy: Content for the study of technology.

International Technology Education Association. (2007). Standards for technological literacy: Content for the study of technology.

Irvin, M. J., Byun, S. Y., Meece, J. L., Farmer, T. W., & Hutchins, B. C. (2012). Educational barriers of rural youth: Relation of individual and contextual difference variables. *Journal of career assessment*, *20*(1), 71-87.

Jolly, J. L. (2009). The National Defense Education Act: Current STEM initiative and the gifted. *Gifted Child Today*, 32(2), 50-53.

Jonassen, D. (1991). Objectivism vs constructivism: Do we need a new philosophical paradigm? *Educational Technology, Research and Development*, 39(3), 5-13.

Joyce, B. A. and S. Farenga (1999). Informal Science Experience, Attitudes, Future Interest in Science, and Gender of High-Ability Students: An exploratory study. *School Science and Mathematics* 99(8): 431-437.

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

Keselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality, *Journal of Research in Science Teaching*, 40 (), 898–921 http://dx.doi.org.ezproxy.lib.vt.edu/10.1002/tea.10115

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry based teaching. *Educational Psychologist*, 41(2), 75-86.

Kolodner, J. L. (2002). Facilitating the learning of design practices: Lessons learned from an inquiry into science education. *Journal of Industrial Teacher Education*, *39*(3).

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *The elementary school journal*, 94(5), 483-497.

Krajcik, J., & Blumenfeld, P. (2005). Project-Based Learning. In R. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (Cambridge Handbooks in Psychology, pp. 317-334). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511816833.020

Krajcik, J., Blumenfeld, P. C., Marx, W. R., Bass, M. K., & Fredricks, J. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences*, 7(3–4), 313–350.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, *41*(4), 212-218.

Lapan, R. T. (2004). Career development across the K–16 years: Bridging the present to satisfying and successful futures. Alexandria, VA: American Counseling Association.

Lazarowitz, R., Hertz-Lazarowitz, R., & Baird J. H. (1994). Learning in a cooperative setting: Academic achievement and affective outcomes. *Journal of Research in Science Teaching, 31,* 1121–1131.

Legum, H. L., & Hoare, C. H. (2004). Impact of a career intervention on at-risk middle school students' career maturity levels, academic achievement, and self-esteem. *Professional School Counseling*, 148-155.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unified social cognitive-theory of career and academic interest, choice, and performance [Monograph]. *Journal of Vocational Behavior*, 45, 79-122.

Levine, T.R. & Hullett, C.R. (2002). Eta Squared, Partial Eta Squared and the Misreporting of Effect Size in Communication Research. *Human Communication Research*, 28, 612-625.

Lou, S. J., Liu, Y. H., Shih, R. C., & Tseng, K. H. (2011). The senior high school students' learning behavioral model of STEM in PBL. *International Journal of Technology and Design Education*, 21(2), 161-183..

Madill, H. M., A.-L. Ciccocioppo, et al. (2004). The Potential to Develop a Career in Science: Young women's issues and their implications for careers guidance initiatives. International *Journal for the Advancement of Counseling*, 26(1): 1-19.

Major, C. H., & Palmer, B. (2001). Assessing the effectiveness of problem-based learning in higher education: Lessons from the literature. *Academic Exchange Quarterly*, 5(1), 4-9.

McMahon, M., & Patton, W. (1997). Gender differences in children and adolescents' perceptions of influences on their career development. *School Counselor*, 44, 368–376.

Mohr-Schroeder, M. J., Jackson, C., Miller, M., Walcott, B., Little, D. L., Speler, L., ... & Schroeder, D. C. (2014). Developing middle school students' interests in STEM via summer learning experiences: See Blue STEM camp. *School Science and Mathematics*, *114*(6), 291-301.

Murphy, C., & Beggs, J. (2005). Primary science in the UK: A scoping study. *Final report to the Wellcome Trust. London: Wellcome Trust*.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2010. *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5.* Washington, DC: The National Academies Press. https://doi.org/10.17226/12999.

National Assessment of Educational Progress (2015). *2014-2015 The Condition of Education*. Retrieved from http://www.nationsreportcard.gov/science-2015/g8-state.aspx.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Retrieved from http://www2.ed.gov/pubs/NatAtRisk/index.html.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. National Academies Press.

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. National Academies Press.

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

National Research Council. (2014). STEM integration in K-12 education: Status, prospects, and an agenda for research. Washington: National Academies Press.

National Science Board (2010). Science and Engineering Indicators: 2010. Retrieved from http://www,nsf.gov/statistics/seind10/c0i.htm.

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in health sciences education*, *15*(5), 625-632.

Oberg, C. (2010). Guiding Classroom Instruction through Performance Assessment. *Journal of Case Studies in Accreditation and Assessment*, 1.

Oberg, C. (2010). Guiding Classroom Instruction through Performance Assessment. *Journal of Case Studies in Accreditation and Assessment*, 1.

Office of Science and Technology Policy (2013). Federal science, technology, engineering, and mathematics (STEM) education 5-year strategic plan. *National Science and Technology Council: Committee on STEM Education.*

Organization for Economic Co-operation and Development (2016). *PISA 2015 PISA Results in focus*. ‘washington, DC: OECD. Retrieved from: https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). London: The Nuffield Foundation.

Ostler, E. (2012). 21st century STEM education: A tactical model for long-range success. *International Journal of Applied Science and Technology*. 2(1), 28-33.

Parker, W. C., & Jarolimek, J. (1997). *Social studies in elementary education*. Upper Saddle River, NJ: Merrill.

PBS Kids. (n.d.). Introducing the design process. Retrieved from http:// www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_TG_De signProcess.pdf

Pedaste, M., & Sarapuu, T. (2006). The factors influencing the outcome of solving story-problems in a Web-based learning environment. *Interactive Learning Environments*, 14(2), 153-176

Pedaste, M., Mäeots, M., Leijen, Ä., & Sarapuu, T. (2012). Improving Students' Inquiry Skills through Reflection and Self-Regulation Scaffolds. *Technology, Instruction, Cognition & Learning*, *9*.

Pell, T., & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education*, 23(8), 847–862.

Phipps, B. J. (1995). Career dreams of preadolescent students. *Journal of Career Development*, 22, 19–32.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93 (3), 223-231

Reider, D., Knestis, K., & Malyn-Smith, J. (2016). Workforce Education Models for K-12 STEM Education Programs: Reflections on, and Implications for, the NSF ITEST Program. J*ournal of Science Education and Technology*, 25(6), 847-858.

Rothwell, J. (2013). The hidden STEM economy. *Washington: Brookings Institution*.

Rural School Community Trust. (2003, February). Why rural matters again: New report on the continuing need for every state to take action on rural education. *Rural Policy Matters*, 5, 1-5.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science(Washington)*, *316*(5824), 548-549.

Sanders, M. (2009). STEM, STEM education, STEM mania. *Technology Teacher,* 68(4), 20-26.

Sanders, M. (2012, December). *Integrative STEM education as "best practice."* Paper presented at the Seventh Biennial International Technology Education Research Conference, Queensland, Australia. Retrieved from www.sp2.upenn.edu/ostrc/stem/documents/IntegrativeSTEM.pdf

Sanders, M. & & Wells, J.G. (2006-2010). Integrative STEM education. Retrieved from http://www.soe.vt.edu/istemed

Schmitt-Wilson, S., & Welsh, M. (2012). Vocational knowledge in rural children: A study of individual differences and predictors of occupational aspirations and expectations. *Learning and Individual Differences*, 22, 862–867.

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

Schultheiss, D. E. P. (2008). Current status and future agenda for the theory, research, and practice of childhood career development. *The Career Development Quarterly*, 57(1), 7-24.

Seligman, L., Weinstock, L., & Heflin, E. N. (1991). The career development of 10 year olds. *Elementary School Guidance and Counseling*, 25, 172–181.

Shoffner, M. F., Newsome, D., Barrio Minton, C. A., & Wachter Morris, C. A. (2015). A qualitative exploration of the STEM career-related outcome expectations of young adolescents. Journal of Career Development, 42(2), 102-116.

Shulman, L. S. (2005). Signature pedagogies in the profession. *Daedalus*, 134(3), 52-59.

Singer, J., Marx, R., Krajcik, J., & Clay-Chambers, J. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist*, 35(3), 165–178.

Skolnik, R. (1995). Doctor, lawyer... Technical chief? *Vocational Education Journal*, 70, 36–37, 55.

Slaton, A. E., & Pawley, A. L. (2015, June), *The Power and Politics of STEM Research Design: Saving the "Small N"* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.2490

Smithrim, K., & Upitis, R. (2005). Learning through the arts: Lessons of engagement. *Canadian Journal of Education/Revue canadienne de l'éducation*, 109-127.

Sneider, C. (2011). A Possible Pathway for High School Science in a STEM World. *Publications.* Paper 159. http://digitalcommons.usu.edu/ncete_publications/159

Solomon, G. (2003). Project-based learning: A primer. *Technology and Learning*, 23(6), 20–30.

Spohn, K., Crowther, T., & Lykins, C. D. (1992). Appalachian access and success: A research project of the Ohio Board of Regents and a consortium of two- and four-year colleges and universities in Appalachian Ohio. Portsmouth, OH: Shawnee State University.

Stanford, P., & Reeves, S. (2005). Assessment that drives instruction. *Teaching Exceptional Children*, 37(4), 18-22.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for Teaching Integrated STEM Education. Journal of Pre-College Engineering Education Research, 2(1), 28–34. doi:10.5703/1288284314653

Super, D. E. (1957). The psychology of careers. New York: Harper.

Super, D. E., Savickas, M. L., & Super, C. M. (1996). The life-span, life-space approach to careers. In D. Brown, L. Brooks, & Associates (Eds.), Career choice and development (3rd ed., pp. 121-178). San Francisco: Jossey-Bass.

Super, D.E. (1990). A life-span, life-space approach to career development. In D. Brown, L. Brooks, & Associates (Eds.), Career choice and development (2nd ed., pp. 197-261). San Francisco: Jossey-Bass.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Life sci*, *1*, 0-2.

Tamir, P. (1991). Practical work in school science: An analysis of current practice. In B. Woolnough (Ed.), Practical science (pp. 14-20). Buckingham: Open University Press.

Tang, M., & Russ, K. (2007). Understanding and Facilitating Career Development of People of Appalachian Culture: An Integrated Approach. [Article]. Career Development Quarterly, 56(1), 34-46.

Tieken, M. (2014). *Why rural schools matter*. Chapel Hill, NC: The University of North Carolina Press.

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics*, 90, 403-418.

Trice, A. D., & Rush, K. (1995). Sex-stereotyping in four-year-olds' occupational aspirations. *Perceptual and Motor Skills*, 81, 701-702.

Trice, A. D., Hughes, M. A., Odom, C., Woods, K., & McClellan, N. C. (1995). The origins of children's career aspirations: IV. Testing hypotheses from four theories. *The Career Development Quarterly*, 43, 307–322.

Trilling B., & Fadel, C. (2012). Twenty-first Century Skills: Learning for Life in Our Times. New York, NY: Jossey-Bass.

U. S. Department of Education, Office of Vocational and Adult Education. (2012). Investing in America's future: A blueprint for transforming career and technical education, Washington, D.C.

U.S. Advisors on Science and Technology. (2010). Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future. *Executive Report). Washington, DC: President's Council of Advisors on Science and Technology*.

U.S. Census Bureau. (2011). *Factfinder*, Retrieved from http://factfinder.census.gov

U.S. Census Bureau. (2014). *Factfinder*, Retrieved from http://factfinder.census.gov

U.S. Department of Education (2015). *Science, Technology, Engineering and Math: Education for Global Leadership*. Retrieved from https://www.ed.gov/stem.

Uden, L. & Beaumont, C. (2006). Technology and problem-based learning. London, UK: Information Science Publishing

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622-639.

van Tuijl, C., & van der Molen, J. H. W. (2016). Study choice and career development in STEM fields: an overview and integration of the research. *International journal of technology and design education*, 26(2), 159-183.

Verner, M. I & Hershko, E. (2003). School graduation project in robot design: A case study of team learning experiences and outcomes. *Journal of Technology Education, 14*(2), 40–55.

Viadero, D. (2005). Scholars eye ‘signature’ method of teacher training. *Education Week*, 25(7), 8-8.

Virginia Department of Education (2012). Governor's STEM academies. Retrieved from http://www.doe.virginia.gov/instruction/career_technical/gov_academies/index.shtml

Virginia Department of Education (2016). Radford School Quality Profile. Retrieved from http://schoolquality.virginia.gov/

von Glasersfeld, E. (1995). Radical constructivism: A way of knowing and learning. London: Palmer Press.

Wagner, T. (2008). Rigor redefined. *Educational Leadership*, 66(2), 20-24.

Walls, R. T. (2000). Vocational cognition: Accuracy of 3rd, 6th, 9th, and 12th grade students. *Journal of Vocational Behavior*, 56, 137–200.

Watson, M., & McMahon, M. (2005). Children’s career development: A research review from a learning perspective. *Journal of Vocational Behavior*, 67, 119–132.

Wells, J. G. (2008). STEM education: The potential of technology education. Paper presented at the 95th Annual Mississippi Valley Technology Teacher Education Conference. St. Louis, Missouri.

Wells, J. G. (2013). Integrative STEM education at Virginia Tech: Graduate preparation for tomorrow's leaders. *Technology and Engineering Teacher*, *72*(5), 28-35.

Wiggins, G. (1990). The case for authentic assessment. *Practical Assessment, Research & Evaluation*, *2*(2), 1-6.

Wilhelm, P., Beishuizen, J.J. (2003). Content effects in self-directed inductive learning, *Learning and Instruction*, 13, pp. 381–402. http://dx.doi.org.ezproxy.lib.vt.edu/10.1016/S0959-4752(02)00013-0

Zhbanova, K.S., Rule, A.C., Montgomery, S.E. et a. (2003). Defining the Difference: Comparing Integrated and Traditional Single-Subject Lessons. *Early Childhood Education Journal,* 38(4), 251–258. doi:10.1007/s10643-010-0405-1

Appendix A

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Physics	Between Groups	.572	2	.286	.355	.703
	Within Groups	63.672	79	.806		
	Total	64.244	81			
Environmental Work	Between Groups	1.566	2	.783	1.157	.320
	Within Groups	53.458	79	.677		
	Total	55.024	81			
Biology	Between Groups	1.930	2	.965	1.081	.344
	Within Groups	70.570	79	.893		
	Total	72.500	81			
Veterinary Work	Between Groups	.214	2	.107	.098	.907
	Within Groups	86.286	79	1.092		
	Total	86.500	81			
Mathematics	Between Groups	.432	2	.216	.195	.824
	Within Groups	87.629	79	1.109		
	Total	88.061	81			
Medicine	Between Groups	3.919	2	1.960	1.607	.207
	Within Groups	96.325	79	1.219		
	Total	100.244	81			
Earth Science	Between Groups	.349	2	.174	.239	.788
	Within Groups	57.749	79	.731		
	Total	58.098	81			
Computer Science	Between Groups	.632	2	.316	.266	.767
	Within Groups	93.759	79	1.187		
	Total	94.390	81			
Medical Science	Between Groups	.675	2	.338	.318	.728
	Within Groups	83.727	79	1.060		
	Total	84.402	81			
Chemistry	Between Groups	.931	2	.466	.505	.605
	Within Groups	72.825	79	.922		
	Total	73.756	81			
Energy/Electricity	Between Groups	1.649	2	.825	.824	.443
	Within Groups	79.095	79	1.001		
	Total	80.744	81			
Engineering	Between Groups	5.896	2	2.948	3.281	.043
	Within Groups	70.982	79	.899		
	Total	76.878	81			

Post Hoc

Dependent Variable		(J) Assigned Group	Mean Difference (I-J)	Std. Error	Sig.	Upper Bound	Lower Bound
		Design-Based Learning	-.488	.266	.165	-1.12	.15
		Scientific Inquiry	.198	.243	.694	-.38	.78
		Traditional	.488	.266	.165	-.15	1.12
		Scientific Inquiry	.686*	.272	.036	.04	1.34
Engineering	Tukey HSD	Traditional	-.198	.243	.694	-.78	.38
		Design-Based Learning	-.686*	.272	.036	-1.34	-.04

*. The mean difference is significant at the 0.05 level.

Appendix B

Scientific Inquiry Lab Report Template

Name: ______________________ Date: ____________ Class: ________

Problem:
What do you want to find out?

Research:
What do you already know?
Research the question.

Hypothesis:
If ____then ____
because ____.

Variables & Controls:

Dependent Variable
The variable that a scientist measures in the experiment

Independent Variable
The variable that will change in the experiment

Set-Up Conditions (Controlled Variables)
The conditions of the experiment that should be kept constant, or the same, so the test is fair.

Procedure:

Materials:

Choose the best tool for your measurements

Measurement	Instrument/Tool	Units
Example: length	Example: Ruler	Example: meters

Data Collect information from the experiment

Results Perform calculations and/or draw a graph

Summary: What happened?

Was your hypothesis correct? How do you know?

Conclusion Do's and Don'ts

Do reference an illustration or a graph you made, if appropriate.
Don't list the data again, but summarize, discuss, and analyze the data.
Do explain why your hypothesis was correct or incorrect from your observations or data.
Don't give the procedure again, but **do** point out possible sources of error.
Don't forget to break up your ideas with more than one paragraph. Your conclusion is an essay.

Format for writing a conclusion

(length of blank lines does NOT indicate the length of your entries – additional sentences are encouraged)

This lab (experiment) investigated ______________________________. In order to study the problem we ______________________________.

My results showed ______________________________, thus proving my hypothesis was (correct/incorrect). I believe the results are (accurate/inaccurate) because ______________. In order to further investigate this problem, next time I would __________.

Conclusion: What happened?

Appendix C

DESIGN CHALLENGE

Problem Scenario

Water from lakes and rivers often has contaminants that make it unfit for drinking. The water may contain dirt, rocks and other objects that can be easily identified, but it may also contain bacteria and other microscopic organisms that cannot be seen easily. For these reasons, water that is delivered to homes must go through a water treatment process. Water treatment is typically a five-part process that consists of aeration, coagulation, sedimentation, filtration and disinfection. The town's existing water treatment filtration system has collapsed and the environmental quality director is looking for a new groundwater filtration device to attach to the new disinfection unit at the water treatment facility.

Your design skills are needed to design the filtration device, which removes most but not all of the impurities from the water.

Materials

Provided:

- 1 water bottle
- 1 cup to simulate the holding chamber for filtered water
- dirty water
- Stopwatch
- Turbidity measurement tool (printed)

Available at a cost:

- cotton balls
- tulle/netting
- tissue
- fabric
- paper towels
- coffee filters
- gravel
- sand
- rubber bands
- additional water bottles
- duct tape

Challenge

Using the engineering design process, build and test and a filtration device. You must consider the materials and costs in your design. The treatment plant treats water for both animal consumption and human consumption.

Each team will have access to the dirty water. There are two levels of filtration needed to supply the treatment facility. Before reaching the treatment facility, water for human consumption ("A" water) must have a turbidity level of <10 NTU. "B water" for plant and animal use must have a turbidity level of <25 NTU. For each 10 ml of water that is filtered, your team will be credited $10 per ml if it meets the human standard, and $5 per ml if it meets the plant/animal standard.

Criteria and Constraints

- Successful designs will filter water for A tank or B tank using only the materials available. Aim for the highest profit (total paid-costs of materials) possible within a 2 minute testing window.
- Tools may be used to alter the materials as necessary for the project.
- For water to be judged and purchased, a materials list and cost sheet for the final product must be provided.
- Filter prototypes must be ready for testing in _____ minutes.
- Unsafe behaviors will disqualify a team from continuing.

To Begin:

1. Brainstorm

Brainstorm with your teammates about possible design features for the optimal filtration device. Record your ideas here by sketching, describing, or a combination of both.

2. Design

Draw and label your first prototype here (sketch or describe additional iterations on additional sheets of paper):

*include amounts of materials planned

3. Build:

Follow your plan and create something. As you cycle through the build stage, make sure to document the changes you make in your prototypes.

4. Data Collection:

List material quantities in order for each prototype	**Turbitity <10 NTU**	**Turbidity <20 NTU**
Prototype 1		
Prototype 2		
Prototype 3		
Prototype 4		

4. Observation

As teams prepare for the timed water collection, organize a "stay and stray" gallery walk with your teammates. You should set up a rotation where one person stays with your filter to answer questions, and the other teammates look more closely at other teams' designs. Ask questions about why and how teams created their designs, and discuss how your designs are similar and different.

5. Reflection

What changes did you make to your prototypes along the way? Why? Did they improve your results? In what ways?